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DEPARTMENT OF THE INTERIOR,
CENSUS OFFICE.

FRANCIS A. WALKER, Superintendent,
Appointed April 1, 1879; resigned November 3, 1881.

CHAS. W. SEATON, Superintendent,
Appointed November 4, 1881. Office of Superintendent abolished March 3, 1885.

REPORT

ON

POWER AND MACHINERY EMPLOYED IN MANUFACTURES,

EMBRACING

STATISTICS OF STEAM AND WATER POWER USED IN THE MANUFACTURE OF IRON AND STEEL, MACHINE TOOLS AND WOOD-WORKING MACHINERY, WOOL AND SILK MACHINERY,

AND MONOGRAPHS ON

PUMPS AND PUMPING ENGINES, MANUFACTURE OF ENGINES AND BOILERS, MARINE ENGINES AND STEAM VESSELS.

PROF. W. P. TROWBRIDGE,
CHIEF SPECIAL AGENT.

ALSO

REPORT ON THE ICE INDUSTRY OF THE UNITED STATES,

BY

HENRY HALL,
SPECIAL AGENT.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1888.

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D. C., June 1, 1888.

SIR: I have the honor to transmit herewith the twenty-second and last volume of the series constituting the final report on the Tenth Census. It consists of seven distinct reports, as follows:

Steam and Water Power used in the Manufacture of Iron and Steel; Machine Tools and Wood-working Machinery; Wool and Silk Machinery; Pumps and Pumping Engines; Manufacture of Engines and Boilers, and Marine Engines and Steam Vessels, compiled under the direction of Professor W. P. Trowbridge, of the School of Mines, Columbia College, New York, chief special agent; and a report upon the Ice Industry of the United States, by Henry Hall, of New York, a special agent of the Census Office.

I have the honor to be, very respectfully,

JAMES H. WARDLE,
Chief of Census Division.

HON. WILLIAM F. VILAS,
Secretary of the Interior.

GENERAL TABLE OF CONTENTS.

LETTER OF TRANSMITTAL.

NEW YORK, N. Y., *September* 25, 1882.

Hon. CHAS. W. SEATON,
Superintendent of Census, Washington, D. C.:

SIR: I have the honor to transmit herewith the following reports of special agents of the Census acting under my supervision and direction in obtaining statistics of "Power and Machinery," to wit:

1. The report of Mr. Herman Hollerith on "Steam and Water Power used in the Manufacture of Iron and Steel."
2. The report of Mr. F. R. Hutton on "Machine Tools and Wood-Working Machinery."
3. The report of Mr. F. R. Hutton on "Pumps and Pumping Engines."
4. The report of Mr. Knight Neftel on "Wool and Silk Machinery."
5. The report of Mr. C. H. Fitch on "Engines and Boilers."
6. The report of Mr. C. H. Fitch on "Marine Engines and Steam Vessels."

These reports exhibit the conditions of the industries to which they relate at the present period in the history of this country.

The report of Mr. Hollerith will be found interesting as showing the gradual increase in the proportion of steam-power over water-power, notwithstanding the increase in the latter. It is not difficult to find reasons for this. In the first place, water-power is not always, nor indeed usually, found conveniently located for the erection of large manufacturing establishments. Accessibility to lines of communication is an important element in connection with the building up of extensive establishments in which power is used, and although many notable instances are found where the water-power afforded by large streams is so favorably located in all respects that manufacturing towns have grown up in the immediate vicinity, supported mainly by the water-power available, yet the general rule in regard to water-power, from the very nature of this power, is a certain degree of isolation and inaccessibility; whereas steam-power is not restricted by the topographical features of a country nor to definite localities.

In the second place, water-power is generally limited in amount and irregular, at any one locality, depending, as it does, upon changeable hydrological conditions; while steam-power may not only be indefinitely increased at any point, but may be made regular and constant from day to day, winter and summer. A large part of the increase in steam-power for certain kinds of manufactures is therefore found to be auxiliary or supplementary to established water-powers, either for the purpose of adding power or for supplying the occasional or periodical deficiencies of water-power.

In this connection I would refer to the reports of Mr. George F. Swain, Mr. James L. Greenleaf, and Mr. Dwight Porter, on the water-power of the whole country, including that which has been utilized and that which is available.

The relative cost of steam-power and water-power in different parts of the country was one of the questions proposed in Mr. Hollerith's investigations, but without much hope of any definite solution. It was apparent from the first that the costs of these two kinds of power have no relation to each other; the cost of steam-power depending upon the cost of plant, fuel, and engineers' wages, mainly, while the cost of water-power depends upon the cost of dams, supply-conduits, and hydraulic motors. The cost of either for any particular locality can thus be determined under local conditions and circumstances only.

The report of Mr. Hutton on "Machine Tools and Wood-Working Machinery" furnishes a condensed but sufficiently comprehensive statement and exposition of the condition of the arts covered by these important aids to industry in this country at the present time.

The two features which are of the greatest importance in American manufacturing industries are the development and general introduction of the principle of interchangeability in the parts of machines and implements

manufactured and employed in the country, and the gradual introduction into our machine-shops and factories of special tools for preparing and shaping materials for the special uses which they are to subserve, either as parts of such machines or implements, or for general use.

These two branches or lines of development are closely related to each other, and have exercised an immense influence in the rapid growth of our national interests. It may be said of both that they had their origin in the characteristic inventive genius of our people, which has been wisely fostered by the national legislature through liberal patent laws enacted from time to time.

Within the memory of men now living, a New England farmer has devoted his winter evenings to the making of wooden clocks for sale, his implements being a knife, a file, and a saw; another has devoted himself, with the aid of his family, to covering buttons by hand; the modest products in each case going far toward the support of the family. The same processes are now accomplished, with great improvement in style and materials, on a large scale in extensive establishments provided with special tools which render hand-work almost unnecessary. These are mere instances to illustrate the changes that have taken place in every branch of human labor through the introduction of special devices now employed in manufacturing.

In the treatment of the materials which form the heavier metallic parts of engines and other machinery, and all varieties of wood-work, the advance has been no less remarkable. Operations now performed at small cost in preparing such materials for use would have been found impossible a few years ago by mere hand-work, or would at least have been impracticable on account of the great expense involved.

It may be affirmed, moreover, that with the multiplication of general and special tools in shops and factories there has been a corresponding advance in the strength, durability, and reliability of the machines and implements produced. The exact time-tables of our railway systems, fulfilled with such wonderful certainty at the present day, and the comparative immunity from stoppages and accidents of our manufacturing and mining machinery, would be unknown elements of modern activity if the machines employed were made wholly by hand.

The heavy operations now employed in welding, turning, boring, and shaping would be impracticable without the modern tools employed for these purposes. Without the steam-hammer the modern propeller-shaft for steam-ships could not be made, while there are hundreds of operations which, though possible by hand, are commercially practicable only through special tools.

The desire of General F. A. Walker, late Superintendent of Census, that the subject of shop-tools and wood-working machinery should receive attention in connection with the statistics of power and machinery led me to secure the services of Mr. F. R. Hutton, assistant in mechanical engineering in the School of Mines, Columbia College, New York, for this special work. Mr. Hutton's acquirements and fitness for this work were well known to me, and I now transmit his report, together with sketches, drawings, cuts, etc., relating to and illustrating the same.

The report will, I believe, be found worthy of a place in the records of the Tenth Census as illustrating the present period of our country's progress in the mechanic arts.

The report of Mr. Hutton on Pumps and Pumping Engines will, I am sure, commend itself to the mechanical engineers of the country. The modern steam-pump is comparatively a recent and exclusively an American invention. It has been copied abroad and has been brought into almost universal use. Variations in details have been introduced by many skillful American inventors, and their numerous designs applicable to pumping with equal facility large and small quantities of water, with lifts from a few feet to many hundred feet, render the American pump one of the most valuable of modern inventions.

The report of Mr. Neftel on Wool and Silk Machinery deals with very old processes in which radical improvements, except in minor details, are hardly to be expected, but the report will be found to contain much that is interesting. Mr. Neftel's report on Flour-milling Machinery has already been transmitted and is published in Vol. III of the final report on Tenth Census.

To the reports of Mr. Fitch, which have already been transmitted, I have now to add his reports on Stationary Engines and Boilers and Marine Engines and Vessels.

The former covers a branch of industry in manufacturing and the application of steam-power in which it is universally acknowledged that this country has taken the lead, while the latter report will be found to contain descriptions of marine engines and vessels of types peculiar to our inland waters, prepared for publication in a form suitable for conveying general information on these subjects which is not generally accessible.

I beg to add, in closing this brief introduction to these reports, that it is my belief that statistical information of the character here presented can be prepared and preserved for future reference and use only under the auspices of the government, and that such information should be procured and published periodically at intervals of twenty or thirty years as part of the record of industrial and national progress.

I have the honor to be, very respectfully, your obedient servant,

W. P. TROWBRIDGE,
Chief Special Agent.

REPORT

ON THE

STATISTICS OF STEAM- AND WATER-POWER

USED IN THE

MANUFACTURE OF IRON AND STEEL

DURING

CENSUS YEAR ENDING MAY 31, 1880.

COMPILED BY

HERMAN HOLLERITH, E. M.,
SPECIAL AGENT.

TABLE OF CONTENTS.

LETTER OF TRANSMITTAL.

WASHINGTON, D. C., *October* 25, 1881.

Professor W. P. TROWBRIDGE,

Chief Special Agent.

SIR: I have the honor to submit herewith the statistics of steam- and water-power used in the manufacture of iron and steel during the census year, from June 1, 1879, to May 31, 1880, embracing complete statistics of power for that year of (1) blast-furnaces, (2) rolling-mills, (3) Bessemer and open-hearth steel-works, (4) crucible, blister, and miscellaneous steel-works, and (5) blomaries and forges. The establishments included under the respective heads are identical with those similarly classified in the *Statistics of Iron and Steel Production*, in Vol. II of the final reports on the Tenth Census; and the data from which the results herewith transmitted have been obtained were taken from the replies to inquiries relating to power contained in the schedules used by Mr. James M. Swank for the collection of the statistics of the manufacture of iron and steel.

Two sets of figures are given, referring, first, to water-wheels and steam-engines in actual operation during the whole or a part of the census year, 1880; and, second, to such as were not in operation during any portion of that year.

These statistics have been prefaced by a short report making such comparisons with the Census of 1870 as were deemed necessary. In this report I have also endeavored to show the relation between power and product and between amount of power used and number of hands employed.

The figures relating to production and number of hands employed have been taken from the *Statistics of Iron and Steel Production*, compiled by Mr. James M. Swank, special agent,

I am, sir, very respectfully, your obedient servant,

HERMAN HOLLERITH,

Special Agent

SUMMARY OF THE STATISTICS OF STEAM- AND WATER-POWER

USED IN THE

MANUFACTURE OF IRON AND STEEL.

The statistics of steam- and water-power used in the manufacture of iron and steel in the census year 1880 are herein summarized and compared, so far as possible, with the statistics of power reported in the Census of 1870.

GRAND SUMMARY.

In the following table the totals of the various iron and steel industries of the United States are given. Two sets of figures are shown, the first referring to such water-wheels and steam-engines as were actually in operation during the whole or a part of the census year 1880; the second set of figures refer to such water-wheels and steam-engines as were not in actual operation during any part of the census year.

Works.	Number of establishments.		Water-power.				Steam-power.						Total horse-power.	
			Number of wheels.		Horse-power.		Number of boilers.		Number of engines.		Horse-power.			
	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.
All iron- and steel-works	781	224	360	94	16,506	4,628	7,237	703	3,205	318	380,741	31,284	397,247	35,912
Blast-furnaces	340	150	62	47	3,327	1,983	2,683	442	882	178	133,476	17,514	136,803	19,497
Rolling-mills	283	41	131	22	8,825	2,100	3,830	244	1,929	130	194,967	12,675	203,792	14,775
Bessemer and open-hearth steel-works	33	3	......	......	....	....	453	5	251	1	36,241	500	36,241	500
Crucible and miscellaneous steel-works	35	2	9	......	620	....	222	6	116	3	14,585	365	15,205	365
Blomaries and forges	90	28	158	25	3,734	545	49	6	27	6	1,472	230	5,206	775

The total capacity of the 454 water-wheels reported was 21,134 horse-power, of which 94 water-wheels with a capacity of 4,628 horse-power, or 21.9 per cent. of the total capacity, were reported as having been idle during the entire census year; 3,523 steam-engines were reported, with a total capacity of 412,025 horse-power, of which 318 engines, equivalent to 31,284 horse-power, or 7.6 per cent. of the total capacity, were reported as not in operation during any part of the census year.

The total capacity of all steam-engines and water-wheels reported was 433,159 horse-power. The power of all steam-engines and water-wheels reported as not in operation during the census year was 35,912 horse-power, or 8.3 per cent. of the total capacity.

The relation between the power in operation and not in operation during the census year in the various iron and steel industries is shown by the following table:

Works.	WATER-POWER.		STEAM-POWER.		TOTAL HORSE-POWER.	
	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
All iron- and steel-works	78.10	21.90	92.41	7.59	91.71	8.29
Blast-furnaces	62.66	37.34	88.40	11.60	87.53	12.47
Rolling-mills	80.78	19.22	93.90	6.10	93.24	6.76
Bessemer and open-hearth steel-works	....	....	98.64	1.36	98.64	1.36
Crucible and miscellaneous steel-works	100 00	....	97.56	2.44	97.66	2.34
Blomaries and forges	87.26	12.74	86.49	13.51	87.04	12.96

The total of 35,912 horse-power, steam and water, which was reported as not in operation during the census year, is divided between the various iron and steel industries as follows, viz: Blast-furnaces, 54.29 per cent.; rolling-mills, 41.14 per cent.; Bessemer and open-hearth steel-works, 1.39 per cent.; crucible, blister, and miscellaneous steel-works, 1.02 per cent.; blomaries and forges, 2.16 per cent.

COMPARISON WITH CENSUS OF 1870.

In the following table the power reported as used in the manufacture of iron and steel in 1880 is compared with the power reported in the Census of 1870, showing the percentages of increase and decrease:

Class of work.	Census year.	WATER-POWER.		STEAM-POWER.		Total power.
		Number of wheels.	Horse-power.	Number of engines.	Horse-power.	
All iron- and steel-works	1880	360	16,506	3,205	380,741	397,247
	1870	393	16,584	1,367	154,091	170,675
Percentage of increase	....	....	....	134.38	147.09	132.75
Percentage of decrease	....	8.40	0.47	....	....	....
Blast-furnaces	1880	62	3,327	882	133,476	136,803
	1870	141	5,034	509	58,866	63,900
Percentage of increase	....	....	....	73.28	126.75	114.09
Percentage of decrease	....	56.03	33.91	....	....	....
Rolling-mills	1880	131	8,825	1,929	194,967	203,792
	1870	162	8,126	744	80,958	89,084
Percentage of increase	....	....	8.60	159.27	140.82	128.76
Percentage of decrease	....	19.14	....	....	....	....
Steel-works	1880	[illegible]	620	367	50,826	51,446
	1870	6	250	83	11,557	11,807
Percentage of increase	....	50.00	148.00	342.17	339.79	335.72
Percentage of decrease	....	....	....	....	....	....
Blomaries and forges	1880	158	3 734	27	1,472	5,206
	1870	84	3,174	31	2,710	5,884
Percentage of increase	....	86.10	17.64	....	....	....
Percentage of decrease	....	....	....	12.90	45.68	11.52

In the Census of 1870 the number of boilers was not reported, hence no comparison can be made.

As the power used in the manufacture of steel was not divided in the Census of 1870, the power used in Bessemer and open-hearth steel-works in 1880 has been added to that used in crucible and miscellaneous steel-works for the purpose of comparison. In this industry the greatest percentage of increase, 336 per cent., is shown; this is due to the large increase in the production of Bessemer and open-hearth steel-works during the last decade, no open-hearth steel and only a comparatively small quantity of Bessemer steel being reported in the Census of 1870.

The next largest percentage of increase, 129 per cent. in the amount of power used, is shown in rolling-mills. The power used in blast-furnaces increased 114 per cent. The power used in blomaries and forges decreased 11.52 per cent.

The total amount of water-power used in 1870 and 1880 was practically the same, the decrease being only 0.47 per cent. The amount of steam-power used, however, increased 147 per cent., giving a total increase of 133 per cent., although the total water-power decreased but 0.47 per cent., the number of water-wheels in use decreased 8.4 per cent.; on the other hand, the number of steam-engines in use increased 134 per cent. These figures tend to show the gradual substitution of steam-power for water-power in the iron- and steel-works of this country.

AVERAGE POWER OF WATER-WHEELS AND STEAM-ENGINES IN 1870 AND 1880.

Water-wheels.—The average power of the water-wheels reported in 1870 was 42.2 horse-power, in 1880 the average was 45.85 horse-power, showing an increase of 8.65 per cent. in the average power of wheels used.

Steam-engines.—In 1870 the average power of the steam-engines reported was 112.72 horse-power, in 1880 the average was 118.79 horse-power, showing an increase of 5.39 per cent. in the average power of engines used.

The following table gives the average power of water-wheels and steam-engines reported as used in the several iron and steel industries in 1880:

Works.	AVERAGE POWER.	
	Water-wheels.	Steam-engines.
	Horse-power.	*Horse-power.*
All iron- and steel-works	45.85	112.72
Blast-furnaces	53.66	151.33
Rolling-mills	67.37	101.07
Bessemer and open-hearth steel-works	....	144.39
Crucible and miscellaneous steel-works	68.89	125.73
Blomaries and forges	23.63	54.52

RELATION BETWEEN STEAM- AND WATER-POWER.

The following table shows the relative importance of steam- and water-power in the various iron and steel industries, as reported in the Censuses of 1880 and of 1870:

Works.	1880.		1870.	
	Water-power.	Steam-power.	Water-power.	Steam-power.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
All iron- and steel-works	4.16	95.84	9.72	90.28
Blast-furnaces	2.43	97.57	7.88	92.12
Rolling-mills	4.33	95.67	9.12	90.88
Bessemer and open-hearth steel-works	....	100.00	....	....
Crucible and miscellaneous steel-works	4.08	95.92	....	....
Blomaries and forges	71.72	28.28	53.94	46.06
All steel-works	1.21	98.79	2.12	97.88

From the foregoing table we see that the relative importance of water-power has decreased in all the iron and steel industries excepting blomaries and forges. In 1870, of the total amount of power used in blomaries and forges, 46 per cent. was steam-power, while in 1880 only 28 per cent. was steam-power. This is easily accounted for when we remember that the product of all the iron and steel industries increased, excepting that of blomaries and forges, which decreased 35 per cent. in the decade from 1870 to 1880.

Mr. Swank, in his *Statistics of Iron and Steel Production* says: "This decrease is due to the general substitution of improved processes for the forges and blomaries of our earlier iron history, and it would have been much greater in the decade mentioned if the improved American blomary, so largely used in northern New York, had not contributed its large product to swell the production of 1880." Hence we would naturally look to New York for this increase in the amount of water-power used. We find that the water-power used in New York in this industry has increased 500 horse-power, the total increase for the whole United States being only 560 horse-power. The northern part of New York state, where these blomaries are located, is peculiarly adapted to the development of water-power. As the cost of manufacturing with water-power is less than with steam-power, other things being equal, the advantages of water-power become more apparent as the competition increases.

The following table shows, first, the amount of water-power used in the iron and steel industries of the different states, as reported in the Censuses of 1880 and of 1870; second, the percentages of the total amount of

water-power used in each state; third, the relative importances of steam- and water-power in each state in 1880 and 1870, giving the percentages of steam- and water-power; and, fourth, the percentages of increase and decrease in the amount of water-power used in each state.

States and territories.	1880.				1870.				Increase since 1870.	Decrease since 1870.
	Water-power.	Total water-power.	Water-power.	Steam-power.	Water-power.	Total water-power.	Water-power.	Steam-power.		
	Horse-power.	*Per cent.*	*Per cent.*	*Per cent.*	*Horse-power.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
The United States	16,506		4.16	95.84	16,584		9.72	90.28		0.47
Alabama				100.00	135	0.81	15.08	84.92		
California				100.00				100.00		
Colorado				100 00						
Connecticut	918	5.56	29.97	70.03	278	1.68	20.78	79.22	230.22	
Delaware	189	1.14	7.39	92.61	65	0.39	8.97	91.03	190.77	
District of Columbia				100.00						
Georgia	53	0.32	3.31	96.69	22	0.13	4.30	95.70	140.91	
Illinois				100.00				100.00		
Indiana				100.00				100.00		
Kansas				100.00						
Kentucky				100.00				100.00		
Maine	785	4.76	41.64	58.36	120	0.72	15.00	85.00	554.17	
Maryland	670	4.06	11.27	88.73	660	3.98	24.19	75.81	1.52	
Massachusetts	1,650	10.00	89.33	10.67	785	4.73	12.61	87.39	110.19	
Michigan	45	0.27	0.86	99.14	95	0.57	2.95	97.05		52.63
Missouri				100.00	66	0.40	2.49	97.51		
Nebraska				100.00						
New Hampshire				100.00						
New Jersey	1,196	7.25	8.01	91.99	1,080	6.51	20.00	80.00	10.74	
New York	4,709	28.53	15.78	84.22	5,718	34.48	31.11	68.89		17.65
North Carolina	253	1.53	100.00		362	2.18	75.89	24.11		30.11
Ohio	100	0.61	0.20	99.80	60	0.36	0.28	99.72	66.67	
Oregon	147	0.89	100.00							
Pennsylvania	3,713	22.49	1.85	98.15	3,864	23.30	4.68	95.32		3.90
Rhode Island				100.00				100.00		
South Carolina					111	0.67	100.00			
Tennessee	293	1.78	4.62	95.38	1,175	7.09	50.76	49.24		75.06
Texas				100.00						
Vermont	25	0.15	6.67	93.33	180	1.09	100.00			86.11
Virginia	1,596	9.67	80.97	19.03	1,598	9.64	76.53	23.47		0.13
West Virginia				100.00	20	0.12	0.46	99.54		
Wisconsin	164	0.99	3.44	96.56	190	1.15	17.51	82.49		13.68
Wyoming				100.00						

By this table we see that the relative importance of water-power has decreased since 1870 in each state in which it was used, except in the following: Maine, Massachusetts, Connecticut, North Carolina, and Virginia.

Of the total amount of power used in Maine in 1880, 42 per cent. was water-power, while in 1870 only 15 per cent. was water-power. In Massachusetts the percentage of water-power used increased from 13 per cent. in 1870 to 89 per cent. in 1880. In Connecticut the water-power was 30 per cent. in 1880 and 21 per cent. in 1870.

The relative economy in the use of water-power increases as the cost of fuel increases; hence, we should expect to find a larger percentage of water-power used in states where fuel is expensive. In addition to the relatively high cost of fuel in New England, the topography of the country is such as to afford abundant water-power; hence it is not surprising that those states should be an exception to the foregoing rule.

In North Carolina in 1880 no steam-power was used, while in 1870, of the total amount of power used in the state, 24 per cent. was steam-power. The total amount of power used in 1870 was 477 horse-power; in 1880 it was only 253 horse-power, showing a decrease of 47 per cent. Again, the production fell from 1,801 tons in 1870 to 439 tons in 1880. In 1870 several blast-furnaces, using steam-power, were in operation; but in 1880 the production of iron and steel was confined entirely to blomaries and forges using water-power.

In Virginia we find that the percentage of water-power used had increased from 77 per cent. in 1870 to 81 per cent. in 1880. From 1870 to 1880 the total amount of power used decreased from 2,088 horse-power to 1,971 horse-power, or 5.6 per cent.; the total product, however, increased from 37,836 tons in 1870 to 55,722 tons in 1880. Notwithstanding this increase in the production, fewer establishments were engaged in the manufacture of iron and steel in 1880 than in 1870, there being but 19 establishments reported in 1880 as against 35 establishments in 1870.

The total amount of steam and water-power, the total amount of water-power, and the total amount of steam-power as reported in the Census of 1880 and in that of 1870, is divided in the following table between the different industries, showing percentage of the total amount used in each.

In the Census of 1870 the power used in steel-works was not divided; hence no figures are given for Bessemer and open-hearth steel-works, nor for crucible steel-works for 1870. The percentage used in the manufacture of steel, all kinds, is, however, given for 1870. For 1880 the percentage used in Bessemer and open-hearth steel-works has been added to that used in crucible and miscellaneous steel-works.

Works.	TOTAL HORSE-POWER.		TOTAL WATER-POWER.		TOTAL STEAM-POWER.	
	1880.	1870.	1880.	1870.	1880.	1870.
	397,247 H. P.	170,675 H. P.	16,506 H. P.	16,584 H. P.	380,741 H. P.	170,675 H. P.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Blast-furnaces	34.44	37.44	20.10	30.35	35.06	38.20
Rolling-mills	51.30	52.19	53.46	49.00	51.21	52.54
Bessemer and open-hearth steel-works	9.12	....	....	....	9.52	....
Crucible and miscellaneous steel works	3.83	....	3.76	....	3.83	....
Blomaries and forges	1.31	3.45	22.62	19.14	0.38	1.76
All steel-works	*a* 12.95	6.92	*a* 3.76	1.51	*a* 12.35	7.50

a These figures were obtained by adding percentage for Bessemer and open-hearth steel-works to crucible and miscellaneous steel-works.

The following table gives the total amount of power used in the manufacture of iron and steel, as reported in the Censuses of 1880 and of 1870, the relative rank in production, the percentage of the total amount of power used, and the percentage of increase and decrease for each state that produced iron or steel in the census years 1870 or 1880:

States and territories.	1880. Rank in production.	1880. Total power.	1880. Percentage of total power.	1870. Rank in production.	1870. Total power.	1870. Percentage of total power.	Percentage of increase since 1870.
The United States	....	397,247	....	....	170,675	....	132.75
			Per cent.				*Per cent.*
Pennsylvania	1	201,282	50.67	1	82,652	48.42	143.53
Ohio	2	50,970	12.83	2	21,334	12.50	138.91
New York	3	29,847	7.51	3	18,379	10.77	64.40
Illinois	4	17,852	4.49	15	3,675	2.15	385.77
New Jersey	5	14,935	3.76	4	5,400	3.16	176.57
Wisconsin	6	4,764	1.20	12	1,085	0.64	339.07
West Virginia	7	8,600	2.16	10	4,395	2.58	95.68
Michigan	8	5,240	1.32	8	3,224	1.89	62.53
Massachusetts	9	15,471	3.89	9	6,225	3.65	148.53
Missouri	10	5,915	1.49	6	2,647	1.55	123.46
Kentucky	11	6,400	1.61	7	3,900	2.29	64.10
Maryland	12	5,946	1.50	5	2,728	1.60	117.96
Indiana	13	4,495	1.13	11	4,940	2.89	*a* 9.01
Tennessee	14	6,338	1.60	14	2,315	1.36	173.78
Alabama	15	2,400	0.60	20	895	0.52	168.15
Virginia	16	1,971	0.50	13	2,088	1.22	*a* 5.60
Connecticut	17	3,063	0.77	16	1,338	0.78	128.92
Georgia	18	1,599	0.40	18	512	0.30	212.30
Delaware	19	2,559	0.64	19	725	0.42	252.97
Kansas	20	1,900	0.48	....	....	....	....
California	21	600	0.15	22	225	0.13	166.67
Maine	22	1,885	0.48	17	800	0.47	135.62
Wyoming	23	455	0.12	....	....	....	....
Rhode Island	24	420	0.11	21	425	0.25	*a* 11.76
New Hampshire	25	755	0.19	....	....	....	....
Vermont	26	375	0.09	24	180	0.11	108.33
Colorado	27	315	0.08	....	....	....	....
Oregon	28	147	0.04	....	....	....	....
Nebraska	29	300	0.08	....	....	....	....
Texas	30	60	0.02	....	....	....	....
North Carolina	31	253	0.06	23	477	0.28	*a* 46.96
District of Columbia	32	135	0.03	....	....	....	....
South Carolina	....	....	....	25	111	0.07	....

a Decrease.

Dividing the whole territory of the United States into four grand divisions, as follows, viz, eastern states southern states, western states and territories, and Pacific states and territories, we have the following statistics of power used in the several divisions:

Divisions.	Number of estab- lishments.	WATER-POWER.		STEAM-POWER.			Total horse-power.
		Number of wheels.	Horse-power.	Number of boilers.	Number of engines.	Horse-power.	
The United States	781	360	16, 506	7, 237	3, 205	380, 741	397, 247
Eastern states	460	269	12, 996	5, 107	2, 041	255, 037	268, 033
Southern states	132	81	3, 054	632	315	33, 207	36, 261
Western states and territories	165	9	309	1, 438	819	91, 127	91, 436
Pacific states and territories	4	1	147	60	30	1, 370	1, 517

The following table gives the percentage of the total power used in each of the divisions:

Divisions.	Total horse-power.	Total water-power.	Total steam-power.
	Per cent.	*Per cent.*	*Per cent.*
Eastern states	67. 47	78. 74	66. 98
Southern states	9. 13	18. 50	8. 72
Western states and territories	23. 02	1. 87	23. 94
Pacific states and territories	0. 38	0. 89	0. 36

The relation between steam- and water-power in each of the divisions is shown in the following table:

Divisions.	Water-power.	Steam-power.
	Per cent.	*Per cent.*
Eastern states	4. 85	95. 15
Southern states	8. 42	91. 58
Western states and territories	0. 34	99. 66
Pacific states and territories	9. 69	90. 31

From this we see that the relative importance of water-power, as compared with steam-power, is greatest in the southern and Pacific states and territories. The largest amount of water-power, however, was used in the eastern states, being 78.74 per cent. of the whole.

The following is the average power of water-wheels reported: Eastern states, 48.3 horse-power; southern states, 37.7 horse-power; western states and territories, 34.3 horse-power; in the Pacific states and territories but one wheel of 147 horse-power is reported.

The average power of the steam-engines reported is as follows: Eastern states, 125 horse-power; southern states, 105.4 horse-power; western states and territories, 111.3 horse-power; Pacific states and territories, 44.3 horse-power.

RELATION OF PRODUCT TO POWER.

The following table shows the number of tons, per horse-power, produced in the different iron and steel industries in 1880 and 1870:

Works.	1880.			1870.		
	Total product.	Total power.	Produced per horse-power.	Total product.	Total power.	Produced per horse-power.
	Tons.	*Horse-power.*	*Tons.*	*Tons.*	*Horse-power.*	*Tons.*
All iron- and steel-works	7, 265, 140	397, 247	18. 29	3, 655, 215	170, 675	21. 42
Blast-furnaces	3, 781, 021	136, 803	27. 64	2, 052, 821	63, 960	32. 13
Rolling-mills	2, 353, 248	203, 792	11. 55	1, 441, 829	89, 084	16. 19
Bessemer and open-hearth steel-works	983, 039	36, 241	27. 12	49, 757	11, 807	4. 21
Crucible and miscellaneous steel-works	75, 275	15, 205	4. 95			
Blomaries and forges	72, 557	5, 206	13, 94	110, 808	5, 884	18. 83
All steel-works	*a* 1, 058, 314	*a* 51, 446	20. 57	49, 757	11, 807	4. 21

a These figures are obtained by adding together the figures for Bessemer and open-hearth and crucible and miscellaneous steel-works.

In 1870 the product per horse-power for all iron and steel works was 21.42 tons, in 1880 it was 18.29 tons, showing a decrease of 3.13 tons or 14.6 per cent. in the product per horse-power.

The product of blast-furnaces in 1870 was 32.13 tons per horse-power, and in 1880 it was 27.64 tons, showing a decrease of 4.49 tons, or 26.6 per cent. in the product per horse-power.

The product per horse-power of rolling-mills was 16.19 tons in 1870 and 11.55 tons in 1880, showing a decrease of 4.64 tons, or 28.7 per cent.

The product per horse-power of steel-works in 1870 was 4.21 tons; in 1880 the product was 20.57 tons per horse-power; this increase is due to the large quantities of Bessemer and open-hearth steel made in 1880.

The product per horse-power of blomaries and forges in 1870 was 18.83 tons; in 1880 it was 13.94 tons, showing a decrease of 4.9 tons, or 26 per cent. in the product per horse-power.

The relation between product and power in the three states producing the largest amount of iron and steel in the census year 1880 is shown in the following table:

Works.	PENNSYLVANIA.				OHIO.				NEW YORK.			
	Months in operation.	Total product.	Total power.	Tons per horse-power.	Months in operation.	Total product.	Total power.	Tons per horse-power.	Months in operation.	Total product.	Total power.	Tons per horse-power.
		Tons.	Horse-power.			Tons.	Horse-power.			Tons.	Horse-power.	
All iron- and steel-works	.....	3,616,668	201,282	17.97	.....	930,141	50,970	18.25	...	598,300	29,847	20.05
Blast-furnaces	9	1,930,311	72,223	26.73	9	548,712	25,388	21.61	9	313,368	11,985	26.15
Rolling-mills	10	1,071,098	96,592	11.09	9	272,094	23,092	11.78	8	163,538	11,997	13.63
Bessemer and open-hearth steel-works.	12	531,881	19,730	26.96	10	108,975	2,400	45.41	12	87,165	2,675	32.58
Crucible and miscellaneous steel-works	11	58,805	11,041	5.33	4	360	90	4.00	9	2,511	1,050	2.39
Blomaries and forges	9	24,573	1,696	14.49	......	....	....	....	10	31,718	2,140	14.82

The following table shows the relation between product and power in the four grand divisions of the United States:

Divisions.	Total product.	Total power.	Tons per horse-power.
	Tons.	Horse power.	
The United States	7,265,140	397,247	18.29
Eastern states	4,671,808	268,033	17.43
Southern states	649,153	36,261	17.90
Western states and territories	1,912,689	91,436	20.92
Pacific states and territories	31,490	1,517	20.76

The relation between product and power in the different states for the census years 1880 and 1870 is shown in the following table:

States and territories.	1880.							1870.					
	Months in operation.	Rank in production.	Total production.	Total power.	PERCENTAGE. Total product.	PERCENTAGE. Total power.	Produced per horse-power.	Rank in production.	Total production.	Total power.	PERCENTAGE. Total product.	PERCENTAGE. Total power.	Produced per horse-power.
			Tons.	Horse-power.	Per cent.	Per cent.	Tons.		Tons.	Horse-power.	Per cent.	Per cent.	Tons.
The United States	....	....	7,265,140	397,247	....	....	18.29	....	3,655,215	170,675	....	....	21.42
Pennsylvania	9	1	3,616,668	201,282	49.78	50.67	17.97	1	1,836,808	82,652	50.25	48.42	22.22
Ohio	9	2	930,141	50,970	12.80	12.83	18.25	2	449,768	21,334	12.30	12.50	21.08
New York	9	3	598,300	29,847	8.24	7.51	20.05	3	448,257	18,379	12.26	10.77	24.39
Illinois	9	4	417,967	17,852	5.75	4.49	23.41	15	25,761	3,675	0.71	2.15	7.01
New Jersey	9	5	243,860	14,935	3.36	3.76	16.33	4	115,262	5,400	3.15	3.16	21.34
Wisconsin	10	6	178,935	4,764	2.46	1.20	37.56	12	42,234	1,085	1.16	0.64	38.93
West Virginia	7	7	147,487	8,600	2.03	2.16	17.15	10	72,337	4,395	1.98	2.58	16.46
Michigan	10	8	142,716	5,240	1.96	1.32	27.24	8	86,679	3,224	2.37	1.89	26.89
Massachusetts	9	9	141,321	15,471	1.95	3.89	9.13	9	86,146	6,225	2.36	3.65	13.84
Missouri	9	10	125,758	5,915	1.73	1.49	21.26	6	94,890	2,647	2.60	1.55	35.85
Kentucky	9	11	123,751	6,400	1.70	1.61	19.33	7	86,732	3,900	2.37	2.29	22.24
Maryland	8	12	110,934	5,946	1.53	1.50	18.66	5	95,424	2,728	2.61	1.60	34.98
Indiana	10	13	96,117	4,495	1.32	1.13	21.38	11	64,148	4,940	1.76	2.89	12.99
Tennessee	7	14	77,100	6,338	1.06	1.60	12.17	14	34,305	2,315	0.94	1.36	14.82
Alabama	10	15	62,986	2,400	0.87	0.60	26.24	20	7,060	895	0.19	0.52	7.89
Virginia	7	16	55,722	1,971	0.77	0.50	28.27	13	37,836	2,088	1.04	1.22	18.12

States and territories.	1880.							1870.					
	Months in operation.	Rank in production.	Total production.	Total power.	PERCENTAGE.		Produced per horse-power.	Rank in production.	Total production.	Total power.	PERCENTAGE.		Produced per horse-power.
					Total product.	Total power.					Total product.	Total power.	
			Tons.	Horse-power.	Per cent.	Per cent.	Tons.		Tons.	Horse-power.	Per cent.	Per cent.	Tons.
Connecticut	10	17	38,061	3,063	0.52	0.77	12.43	16	25,305	1,338	0.69	0.78	18.91
Georgia	9	18	35,152	1,599	0.48	0.40	21.98	18	9,634	512	0.26	0.30	18.81
Delaware	11	19	33,918	2,559	0.47	0.64	13.25	19	8,307	725	0.23	0.42	11.45
Kansas	5	20	19,055	1,900	0.26	0.48	10.03	....	....	....	....	....	....
California	12	21	14,000	600	0.19	0.15	23.33	22	3,000	225	0.08	0.13	13.33
Maine	7	22	10,866	1,885	0.15	0.48	5.76	17	17,138	800	0.47	0.47	21.42
Wyoming	9	23	9,790	455	0.15	0.12	21.52	....	....	....	....	....	....
Rhode Island	10	24	8,134	420	0.11	0.11	19.37	21	4,415	425	0.12	0.25	10.39
New Hampshire	12	25	7,978	755	0.11	0.19	10.57	....	....	....	....	....	....
Vermont	7	26	6,620	375	0.09	0.09	17.65	24	1,525	180	0.04	0.11	8.47
Colorado	4	27	4,500	315	0.06	0.08	14.29	....	....	....	....	....	....
Oregon	9	28	3,200	147	0.04	0.04	21.77	....	....	....	....	....	....
Nebraska	10	29	2,000	300	0.03	0.08	6.67	....	....	....	....	....	....
Texas	6	30	1,400	60	0.02	0.02	23.33	....	....	....	....	....	....
North Carolina	7	31	439	253	0.005	0.06	1.74	23	1,801	477	0.05	0.28	3.78
District of Columbia	6	32	264	135	0.005	0.03	1.96	....	....	....	....	....	....
South Carolina	....	....	....	....	....	....	....	25	443	111	0.01	0.07	3.99

In the following table this same relation between product and power is shown for all counties in the United States producing 80,000 tons and upward of iron or steel, or using 4,000 horse-power or more:

Counties.	States.	Months in operation.	Total product.	Total power.	Produced per horse-power.
			Tons.	Horse-power.	Tons.
Allegheny	Pennsylvania	10	848,146	65,327	12.98
Lehigh	do	10	324,875	15,150	21.44
Northampton	do	11	322,882	11,530	28.00
Cambria	do	12	260,140	17,013	15.29
Cook	Illinois	10	248,479	11,962	20.77
Dauphin	Pennsylvania	10	223,676	4,927	45.40
Mahoning	Ohio	10	219,957	12,725	17.29
Berks	Pennsylvania	9	213,580	9,516	22.44
Cuyahoga	Ohio	9	210,354	7,200	29.22
Mercer	Pennsylvania	9	182,881	6,274	29.15
Rensselaer	New York	11	177,967	7,460	23.86
Montgomery	Pennsylvania	9	168,628	7,610	22.16
Lackawanna	do	11	151,273	14,729	10.27
Milwaukee	Wisconsin	11	128,191	3,820	33.56
Saint Louis	Missouri	7	102,644	5,585	18.38
Lawrence	Pennsylvania	8	88,443	4,009	22.06
Lancaster	do	8	87,019	3,753	23.19
Ohio	West Virginia	10	84,767	5,658	14.98
Will	Illinois	12	84,094	2,056	40.90
Chester	Pennsylvania	9	78,363	5,667	13.83
Trumbull	Ohio	10	73,369	4,339	16.91
Lebanon	Pennsylvania	11	73,149	4,170	17.54
Lawrence	Ohio	11	70,794	4,459	15.88
Philadelphia	Pennsylvania	9	65,983	5,168	12.77

In the foregoing tables, showing the relation of product to power, there are great variations in the amount produced per horse-power. Thus, in Illinois the product is 23.41 tons per horse-power, while in Massachusetts it is but 9.13 tons per horse-power. This apparent discrepancy is explained by the fact that the average production per horse-power for blast-furnaces is 27.64 tons; for Bessemer and open-hearth steel-works, 27.12 tons per horse-power; while for rolling-mills it is only 11.55 tons. By an examination of the *Statistics of Iron and Steel Production*, it is found that in Illinois 49.12 per cent. of the total product is from Bessemer and open-hearth steel-works, 22.84 per cent. from blast-furnaces, and 28.01 per cent. from rolling-mills; hence it is not surprising to find here a much larger product per horse-power than in Massachusetts, where of the total product, 77.31 per cent. is produced in rolling-mills; 6.75 per cent. in blast-furnaces, and 15.81 per cent. in Bessemer and open-hearth steel-works. Again, the product per horse-power will not only vary with the different iron and steel industries, but also with different establishments of the same kind according to the character of the product. Thus, a rolling-mill producing large sizes of bar-iron and other large units will not require as much power per ton of product as a mill producing small

rods, hoop-iron, cut-nails, and the like. By a glance at the statistics of production of rolling-mills, we see that the product of the Massachusetts rolling-mills is largely composed of rods, hoop-iron, cut-nails, fish-plates, and such other products as would tend to increase the relative amount of power used. Again, in Massachusetts a large proportion of the power reported is water-power; hence it is very probable that much of the steam-power used is merely as an auxiliary during the dry season. Therefore the total amount of power reported may be somewhat in excess of the amount actually in use in the manufacture of iron and steel.

In examining these figures, the time which the different establishments were in actual operation must be considered. For 1880 the average number of months in operation has been given; unfortunately, this cannot be done for 1870, as no provision was made in the Ninth Census for this item.

On examination of the table on page 7 we find that during 1880 the largest production per horse-power was in the state of Wisconsin, being 37.56 tons. The *Statistics of Iron and Steel Production* show that 66.1 per cent. of the total product was produced in blast-furnaces, and 33.9 per cent. in rolling-mills; the 60,653 tons of rolling-mill product consisted of 31,101 tons of bar-iron, and 29,552 tons of iron rails, all of which was produced by one establishment. The 118,282 tons of pig-iron were produced by 13 blast-furnace stacks, giving an average annual production of 9,099 tons per stack. The average production per stack in Pennsylvania was 8,179 tons; in Ohio, 6,611 tons, and in New York, 6,964 tons.

This will easily account for the very large production per horse-power, as the rolling-mills and blast-furnaces were running under very favorable circumstances as regards the economy of power.

RELATION BETWEEN THE AMOUNT OF POWER USED AND THE NUMBER OF HANDS EMPLOYED.

The following table shows the relation between the power used and the number of hands employed in the various iron and steel industries of the United States for the census years 1880 and 1870:

Works.	1880.			1870.		
	Total power.	Number of hands employed.	Horse-power per hand.	Total power.	Number of hands employed.	Horse-power per hand.
	Horse-power.			*Horse-power.*		
All iron- and steel-works	307,247	140,978	2.82	170,675	77,555	2.20
Blast-furnaces	136,803	41,875	3.27	63,900	27,554	2.32
Rolling-mills	203,792	80,133	2.54	89,084	44,662	1.99
Bessemer and open-hearth steel-works	36,241	10,835	3.34	11,807	2,437	4.84
Crucible and miscellaneous steel-works	15,205	5,196	2.93			
Blomaries and forges	5,206	2,939	1.77	5,884	2,902	2.03
All steel-works	51,446	16,031	3.21	11,807	2,437	4.84

The above table shows that for all iron and steel industries the ratio of power used to hands employed increased from 2.20 horse-power in 1870 to 2.82 horse-power in 1880, or an increase of 27 per cent.; in blast-furnaces this ratio was 2.32 horse-power in 1870, and 3.27 horse-power in 1880, showing an increase of 41 per cent.; for rolling-mills this increase was from 1.99 horse-power in 1870 to 2.54 horse-power in 1880, or 28 per cent.; in blomaries and forges the amount of power used to each hand employed decreased from 2.03 horse-power in 1870 to 1.77 horse-power in 1880, or 13 per cent.

The following table shows the same relation in the states of Pennsylvania, Ohio, and New York:

Works.	PENNSYLVANIA.			OHIO.			NEW YORK.		
	Number of hands employed.	Total power.	Horse-power per hand.	Number of hands employed.	Total power.	Horse-power per hand.	Number of hands employed.	Total power.	Horse-power per hand.
		Horse-power.			*Horse-power.*			*Horse-power.*	
All iron- and steel-works	57,952	201,282	3.47	20,071	50,970	2.54	11,444	29,847	2.61
Blast-furnaces	13,460	72,223	5.37	8,944	25,388	2.84	2,518	11,985	4.76
Rolling-mills	34,998	96,592	2.76	10,266	23,092	2.25	5,532	11,997	2.17
Bessemer and open-hearth steel-works	4,754	19,730	4.15	821	2,400	2.92	1,650	2,675	1.62
Crucible and miscellaneous steel-works	4,080	11,041	2.71	40	90	2.25	255	1,050	4.12
Blomaries and forges	660	1,696	2.57	....	....	....	1,489	2,140	1.44

On comparing the statistics of power used in manufacture with the statistics of production of iron and steel, there appears to be a discrepancy between the increase in the total amount of power used and the increase in the total weight of all products. Thus the increase in the total amount of power used was 132.75 per cent., while the

increase in total weight of all products was only 98.76 per cent. The increase in value of all materials used was 41 per cent.; the increase in value of products was 43 per cent. That is to say, the increase in the value of raw materials in process of manufacture was relatively greater in 1880 than in 1870. This might be due to the fact that the expenditure for wages was relatively greater, but we find that the total amount paid in wages increased only 36.93 per cent. As the use of machinery increases, the amount of power used will increase proportionately. These facts indicate the introduction of mechanical processes and labor-saving machinery, which we know to have been the case.

Although the average production per horse-power has decreased from 21.4 tons in 1870 to 18.3 tons in 1880, the average production to each hand employed has increased from 47.1 tons in 1870 to 51.5 tons in 1880. This is undoubtedly largely due to the fact that the amount of power used to each hand employed has increased from 2.2 horse-power in 1870 to 2.8 horse-power in 1880.

TABLE SHOWING POWER USED IN THE MANUFACTURE OF IRON AND STEEL.

Census year 1880.	NUMBER OF ESTABLISHMENTS.		WATER-POWER.				STEAM-POWER.						TOTAL HORSE-POWER.	
			Number of wheels.		Horse-power.		Number of boilers.		Number of engines.		Horse-power.			
	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.
BLAST-FURNACES.														
The United States	340	150	62	47	3,327	1,983	2,683	442	882	178	133,476	17,514	136,803	19,497
Alabama	7	5		2		50	39	14	16	5	2,140	410	2,140	460
Connecticut	6	2	6		413		2	3	1	1	60	60	473	60
Georgia	5	4		2		35	15	3	5	2	1,000	150	1,000	185
Illinois	3	4					38	32	16	11	2,045	2,967	2,045	2,967
Indiana	3						17		7		675		675	
Kentucky	9	10					51	25	24	14	1,325	1,173	1,325	1,173
Maine	1		2		185								185	
Maryland	12	4	5	1	220	40	53	8	20	6	1,531	215	1,751	255
Massachusetts	2	2	1	1	40	20	12	3	5	2	220	40	260	60
Michigan	13	7	2	2	45	60	50	13	45	12	2,095	610	2,140	670
Minnesota		1						4		2		140		140
Missouri	4	8		3		180	51	17	22	9	2,130	753	2,130	933
New Jersey	12	1	3		325		101	9	18	4	5,224	170	5,549	170
New York	30	9	8	8	572	433	236	66	59	8	11,413	1,000	11,985	1,433
North Carolina		5		6		245		7		4		200		445
Ohio	62	20					409	61	162	26	25,388	3,133	25,388	3,133
Oregon	1		1		147								147	
Pennsylvania	136	31	20	6	1,030	138	1,488	128	422	49	71,193	4,785	72,223	4,923
Tennessee	9	9	2	3	26	64	33	19	14	7	1,810	908	1,836	972
Texas	1						1		1		60		60	
Utah		2		1		80		1		1		20		100
Vermont	1		1		25								25	
Virginia	8	21	5	10	135	543	13	24	6	11	260	665	395	1,208
West Virginia	8	4		2		95	41	3	18	2	3,167	65	3,167	160
Wisconsin	7	1	6		164		33	2	21	2	1,740	50	1,904	50
ROLLING-MILLS.														
The United States	283	41	131	22	8,825	2,100	3,830	244	1,929	130	194,967	12,675	203,792	14,775
Alabama	1	1					5		4		260		260	
California	1						43		16		600		600	
Colorado	1						7		4		315		315	
Connecticut	8		1		225		30		17		1,515		1,740	
Delaware	7	2	2		189		63	5	32	5	2,370	400	2,559	400
District of Columbia	1						3		2		135		135	
Georgia	1	1					18	10	9	2	540	300	540	300
Illinois	7	1					74	6	66	1	8,372	250	8,372	250
Indiana	7	2					60	17	53	20	3,820	1,220	3,820	1,220
Kansas	2						21		12		1,900		1,900	
Kentucky	7	1					93	15	50	12	5,050	1,350	5,050	1,350
Maine	2		4		600		33		10		1,100		1,700	
Maryland	5		6		450		82		48		3,687		4,137	
Massachusetts	18	4	37	4	1,590	300	307	23	103	10	13,001	850	14,591	1,150
Michigan	2						42		18		3,100		3,100	
Missouri	4	2					30	6	17	8	1,485	2,600	1,485	2,600
Nebraska	1						5		5		300		300	

Table showing power used in the manufacture of iron and steel—Continued.

Census year 1880.	Number of establishments.		Water-power.				Steam-power.						Total horse-power.	
			Number of wheels.		Horse-power.		Number of boilers.		Number of engines.		Horse-power.			
	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.
ROLLING-MILLS—Continued.														
New Hampshire	1						27		10		745		745	
New Jersey	12	2	11	8	445	1,000	199	13	98	4	6,575	450	7,020	1,450
New York	19	4	22	6	2,312	201	296	16	120	6	9,685	400	11,997	601
Ohio	34	10	1		100		411	73	256	35	22,992	3,050	23,092	3,050
Pennsylvania	124	7	29		1,545		1,824	52	876	24	95,047	1,305	96,592	1,305
Rhode Island	1	1					14	8	5	8	420	500	420	500
Tennessee	4						35		23		3,165		3,165	
Utah		1		1		80								80
Virginia	3	2	15	3	1,369	519	1		1		40		1,409	519
West Virginia	8						62		32		5,433		5,433	
Wisconsin	1						35		32		2,860		2,860	
Wyoming	1						10		10		455		455	
BESSEMER AND OPEN-HEARTH STEEL-WORKS.														
The United States	33	3					453	5	251	1	36,241	500	36,241	500
Illinois	5						85		44		7,411		7,411	
Kentucky	1						1		1		15		15	
Massachusetts	2						5		2		450		450	
Missouri	1						34		19		2,200		2,200	
New Hampshire	1						3		1		10		10	
New Jersey	a 1													
New York	2						59		47		2,675		2,675	
Ohio	5						37		20		2,400		2,400	
Pennsylvania	13	[illegible]					213	5	113	1	19,730	500	19,730	500
Rhode Island		1												
Tennessee	1						6		3		1,000		1,000	
Vermont	1						10		1		350		350	
CRUCIBLE AND MISCELLANEOUS STEEL-WORKS.														
The United States	35	2	9		620		222	6	116	3	14,585	365	15,205	365
Connecticut	3		4		280		14		4		570		850	
Illinois	1						1		1		24		24	
Kentucky	1						1		1		10		10	
Maryland		1						1		1		15		15
Massachusetts	1						4		2		150		150	
New Jersey	4	1	3		200		28	5	13	2	1,790	350	1,990	350
New York	3						26		10		1,050		1,050	
Ohio	2						2		1		90		90	
Pennsylvania	20		2		140		146		84		10,901		11,041	
BLOMARIES AND FORGES.														
The United States	90	28	158	25	3,734	545	49	6	27	6	1,472	230	5,206	775
Georgia	3		4		53		1		1		6		59	
Maryland	1						10		1		58		58	
Massachusetts	1		1		20								20	
Missouri	1	2		2		120	3	1	2	1	100	25	100	145
New Jersey	7		9		226		3		4		150		370	
New York	20	2	52	1	1,825	30	9		5		315		2,140	30
North Carolina	6	9	13	3	253	40		1		1		15	253	55
Ohio	[illegible]	1						1		1		100		100
Pennsylvania	28	5	50	8	998	158	18		11		698		1,696	158
Tennessee	15	5	20	6	267	102	1		1		70		337	102
Vermont		2		2		40		3		3		90		130
Virginia	8	2	9	3	92	55	4		2		75		167	55

a The power of this establishment is included in crucible steel-works.

Table showing power used in the manufacture of iron and steel—Continued.

Census year 1880.	NUMBER OF ESTABLISHMENTS.		WATER-POWER.				STEAM-POWER.						TOTAL HORSE-POWER.	
			Number of wheels.		Horse-power.		Number of boilers.		Number of engines.		Horse-power.			
	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.	In operation.	Not in operation.
BY STATES.														
The United States	781	224	360	94	16,506	4,628	7,237	703	3,205	318	380,741	31,284	397,247	35,912
Alabama	8	6		2		50	44	14	20	5	2,400	410	2,400	460
California	1						43		16		600		600	
Colorado	1						7		4		315		315	
Connecticut	17	2	14		918		46	3	22	1	2,145	60	3,063	60
Delaware	7	2	2		189		63	5	32	5	2,370	400	2,559	400
District of Columbia	1						3		2		135		135	
Georgia	9	5	4	2	53	35	34	13	15	4	1,546	450	1,599	485
Illinois	16	5					198	38	127	12	17,852	3,217	17,852	3,217
Indiana	10	2					77	17	60	20	4,495	1,220	4,495	1,220
Kansas	2						21		12		1,900		1,900	
Kentucky	18	11					146	40	76	26	6,400	2,523	6,400	2,523
Maine	3		6		785		33		10		1,100		1,885	
Maryland	18	5	11	1	670	40	145	9	69	7	5,276	230	5,946	270
Massachusetts	24	6	39	5	1,650	320	328	26	112	12	13,821	890	15,471	1,210
Michigan	15	7	2	2	45	60	92	13	63	12	5,195	610	5,240	670
Minnesota		1						4		2		140		140
Missouri	10	12		5		300	118	24	60	18	5,915	3,378	5,915	3,678
Nebraska	1						5		5		300		300	
New Hampshire	2						30		11		755		755	
New Jersey	36	4	26	8	1,196	1,000	331	27	133	10	13,739	970	14,935	1,970
New York	74	15	82	15	4,709	664	626	82	241	14	25,138	1,400	29,847	2,064
North Carolina	6	14	13	9	253	285		8		5		215	253	500
Ohio	103	31	1		100		859	135	439	62	50,870	6,283	50,970	6,283
Oregon	1		1		147								147	
Pennsylvania	321	45	101	14	3,713	296	3,689	185	1,506	74	197,569	6,590	201,282	6,886
Rhode Island	1	2					14	8	5	3	420	500	420	500
Tennessee	29	14	22	9	293	166	75	19	41	7	6,045	908	6,338	1,074
Texas	1						1		1		60		60	
Utah		3		2		160		1		1		20		180
Vermont	2	2	1	2	25	40	10	3	1	3	350	90	375	130
Virginia	19	25	29	16	1,596	1,117	18	24	9	11	375	665	1,971	1,782
West Virginia	16	4		2		95	103	3	50	2	8,600	65	8,600	160
Wisconsin	8	1	6		164		68	2	53	2	4,600	50	4,764	50
Wyoming	1						10		10		455		455	

REPORT

ON

MACHINE TOOLS AND WOOD-WORKING MACHINERY,

BY

F. R. HUTTON, M. E.,
SPECIAL AGENT.

TABLE OF CONTENTS.

REPORT ON MACHINE-TOOLS AND WOOD-WORKING MACHINERY.

LIST OF ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

NEW YORK, *December* 8, 1881.

Prof. W. P. TROWBRIDGE.

SIR: I have the honor to transmit herewith the report upon Shop-tools, which I have prepared for the Tenth Census of the United States.

This report has been divided into two parts. The first part treats of tools for working metals, or machine-tools, properly so called. The second part treats of wood-working machinery. It was necessary to define the limits of classification in both divisions, in order that the expansion in the sub-classes should not carry the discussion into too broad a field. For this reason it was decided to begin with the materials as they are bought in the market. The tools for the fabrication of the metals into merchant forms are therefore excluded, and the forest sawing-machines for lumber. At the other end of the series, the line has been drawn at the tools which are distinctly special, or which are designed for one particular duty and can not be applied for any other. Between these boundaries, however, lies a very large class of machines which may be made of very wide application, according to the skill of their operators. These are the tools used in building other tools or constructions, and which, therefore, are more fundamental than they. They are, in short, the tools used in the constructive arts rather than in manufactures. Even with this limitation at both ends the field of study is still a wide one, and it is one in which American industry has been particularly active. The standard of mechanical excellence which is imposed by our best engineers demands a high standard in the tools for the construction of such work. The necessity for exact dimensions in machine-work has stimulated designers to arrange their material so that inaccuracy or spring shall be eliminated in the lines of tool travel. Fuller appreciation of the meaning of "bearing-surface" and its importance in tool-building makes the newer tools more durable as well as more exact. There are also other details of design and construction, which will be made evident from the illustrations in the sequel, which are confirmatory of the progress in this direction. It is hoped that the degree of advancement marked by the types discussed will serve as a stimulus to further effort and as a plane of reference to gauge the upward course in this particular during the next decade.

In the preparation of this report I obtained information at first-hand. Visits were paid to the leading centers of tool industry, and the details were ascertained from personal inspection. I would take this occasion to express my obligation to those gentlemen who have so kindly seconded my efforts in gathering accurate details. The uniform courtesy which it was my good fortune to enjoy in cities lying between Boston and Saint Louis has made the discharge of my duties particularly agreeable, especially when it is remembered that the collection of mechanical statistics of this sort is an entirely novel thing. In a very few cases only has information been gathered by correspondence and from catalogues. Catalogues are usually out of date before they are in circulation, and where they have been used care was taken to make sure of their accuracy.

The places visited are included in the list below. Many of them are the centers where many builders are to be found together, and are therefore of deserved importance:

In Connecticut: Danbury, Essex, Hartford, Middletown, New Haven, Norwich, Wolcottville.

In Delaware: Wilmington.

In Massachusetts: Boston, Chicopee, East Brookfield, Fitchburg, Greenfield, Hyde Park, Leeds, Lowell, New Bedford, Northampton, Springfield, Taunton, Westfield, Winchendon, Worcester.

In Illinois: Chicago, Dunleith.

In Maine: Gardiner.

In Michigan: Battle Creek, Detroit, Grand Rapids.

In Missouri: Saint Louis.

In New Hampshire: Concord, Lebanon, Manchester, Nashua.

In New Jersey: Newark, Smithville.

In New York: Buffalo, New York, Rochester, Syracuse, Yonkers.

In Ohio: Alliance, Cincinnati, Cleveland, Dayton, Defiance, Hamilton, Salem.

In Pennsylvania: Erie, Montgomery, Montrose, Philadelphia, Williamsport.

In Rhode Island: Pawtucket, Providence.

In Vermont: Windsor.

With regard to the illustrations, they are, in a majority of cases, from photographs taken directly from the tool. In many cases they are reproduced from cuts which were themselves from photographs. In a few instances the older types are shown, that comparisons may be instituted with the newer designs. There are but few illustrations of unique tools. Nearly all may be considered to exhibit types either of classes or of particular modifications under those classes. It is thought that their number adds particular interest and value to the report.

It is, of course, unavoidable that this report should not contain what is the very latest type of practice at the date of its publication. Invention and industry are so active that improvements are in the market on tools discussed in the first pages before the last pages are penned. It could only be attempted to bring the facts down to the close of the year 1880, and to leave them there. Nor should it be forgotten in these days of specialization of knowledge, how easy it is for any one fact or group of facts to escape the notice of an individual geographically distant from the center whence they proceed or where they are well known. Allowance must be claimed for shortcomings in this regard also. With these words of explanation, I place the report in your hands.

Yours, respectfully,

F. R. HUTTON,
Special Agent, Tenth Census.

PART I.

MACHINE-TOOLS.

PART II.

WOOD-WORKING MACHINERY.

INTRODUCTORY.

It is proposed in this report to review those shop-tools which have become essentials in engineering establishments, such as machine-shops, car-shops, and the like. The purely metallurgical machinery will therefore be excluded, as also the log-sawing machinery and those special machines which are adapted for but one service and the manufacture of one article.

Shop-tools are to supplement and to replace hand-labor. They have two functions. The first and most general is the conversion of metal and of wood into the special forms required for industrial uses. The second function is the performance upon the shaped pieces of the various operations necessary for finishing and fitting. The differences in structure of wood and of the metals are very great, both mechanically and economically, and give rise to very different forms of tools. It will be necessary to take up the two classes separately. The machines for working in metals are known as machinists' tools, or machine-tools. Machines for converting lumber are called wood-working machinery.

The machines for shaping and fitting metals may act by—

A.—Compressing.
B.—Shearing.
C.—Paring.
D.—Milling.
E.—Abrading, or grinding.

The wood-working tools act by—

F.—Scission, or cutting off the fibers.
G.—Paring, or shaving the surface.
H.—Combinations of these two.
I.—By abrading or grinding.

This classification takes account of the precedence of conversion of the material to the fitting operations. This arrangement will be followed in the succeeding discussions.

Part I.—MACHINE-TOOLS.

A.—TOOLS ACTING BY COMPRESSION.

§ 1.

To the class of tools acting by compression belong—

Squeezers for puddled balls.
Roll-trains.
Hammers.
Riveters.
Die-forging presses.
Bending-rolls, straightening- and bending-presses, and assembling-presses.

The squeezers and roll-trains belong to the metallurgical stage of the manufacture of the metal, previous to its delivery to the engineering establishment in merchant form. By the plan of the review, these do not come up for discussion. The first great class will therefore be the division of Hammers.

HAMMERS.

The mechanical hammers act upon the softened metal to change its shape to that desired. They may be driven from the shafting of the shop through belting, or else directly by the steam of the boiler. The first class may be called "power hammers" and may be subdivided into—

Cam-hammers—trip, tilt.
Crank-hammers.
Friction- or drop-hammers.

§ 2.

CAM-HAMMERS.

This type of hammer in its various forms is historically the earliest. Its construction was no doubt suggested by that of the ordinary hand-hammer. In one of its forms (Figs. 1 *a* and 1 *b*) a long helve of wood with a steel head is pivoted at a point behind the center of its length, and the projecting tail is depressed by wipers upon a cam at the back of all. The rise of the head is stopped by a transverse stringer of wood just after the tail of the helve is released from the wiper, and the elasticity of the helve increases the intensity of the blow. Otherwise it could be no greater than that due to the weight of the head. A greater number of blows can also be made per minute, since gravity is assisted in the arrest of the rise and by the downward impulse upon the delivery of the blow. A second form of this type has the cam-shaft between the head and the center of motion (Figs. 2 *a* and 2 *b*). The wipers bear upon a lifter, and the tail of the hammer strikes upon a wooden spring at the rear, causing the rebound. This arrangement has the advantage over the other of lowering the supports of the cam-shaft, and of

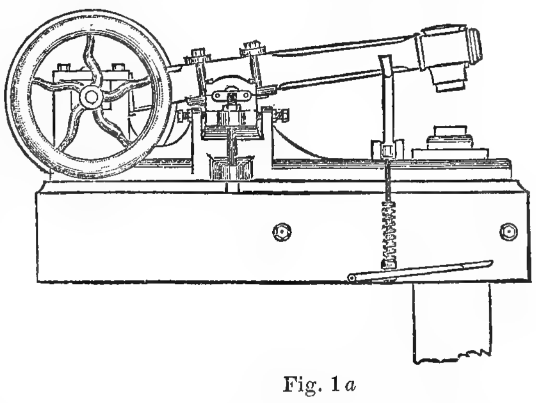


Fig. 1 *a*

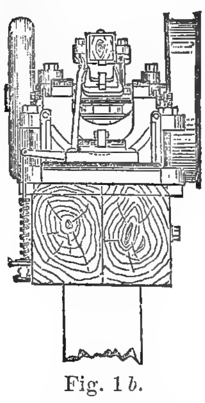


Fig. 1 *b*.

lengthening the helve segment from anvil to husk without increasing the floor space required. This latter form is, therefore, predominant in the newer types. The hammer is driven by a belt running loose upon a flanged pulley on the wiper-shaft, and engaged by a tightener-pulley pressed against the belt by a foot-treadle which surrounds the anvil. There is also a fly-wheel on the cam-shaft to equalize the variable strain upon it by serving as a reservoir of living force. By varying the tension of the driving-belt, the operator can vary the speed, and hence the intensity of the blows. When the belt slips somewhat the wooden spring is less compressed. There are usually several wipers in the cam-wheel, so that several blows are struck in each revolution. The acting surfaces are of steel let into a holder of cast iron and secured by keys, or else dovetailed. The lip on the tail or at the belly of the helve is also of steel, clamped in place by bolts. These bolts pass through ears in a cap, which overhangs the edges of the helve, so that the bolts do not pass through the wood, but outside of it. The trunnions may be secured to the helve in the same way. The head of the hammer has often been similarly secured, but the shocks and vibrations at this point have been found to crystallize bolts made of the most fibrous iron. Newer practice makes the head and trunnion forging in a ring-form. The helve passes through them and they are secured by wedges. This form absorbs its own vibrations, as they are nowhere suddenly arrested. The lower part of the head is fitted with a dovetail groove, in which the flat face or the various swages may be keyed. The anvil-block, with the face or swage similarly keyed, rests upon a post, either driven into the ground or resting upon the timber foundation of the machine. The pivots for the trunnions are made adjustable longitudinally by set-screws and jam-nuts, so as to bring the dies into any desired lateral relation. The foundation is made of a crib-work of timbers bolted together, but yielding sufficiently to take up the shocks imparted to them. The flexible and elastic belt prevents the shocks upon the cams from being carried entirely to the line shafting. Sufficient strain is thus transmitted, however, to necessitate heavier designs than are adapted for steady transmissions.

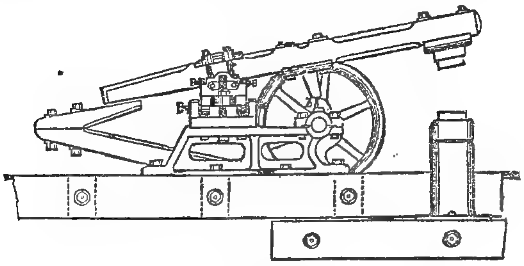


Fig. 2 *a*.

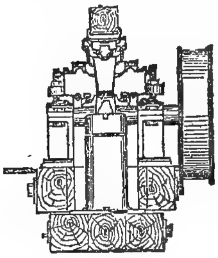


Fig. 2 *b*.

For small work in gun-shops a form of "pony" trip-hammer has been successfully used. The helve and husk and bed-plate are of iron, and the cam-wheel, 10 inches in diameter, makes from 150 to 200 revolutions per minute. There are six cams on the wheel, inserted and held in place by pins. The rapidity of their blows adapts them for small work which is liable to cool rapidly.

It will be at once seen that certain difficulties surround the use of the trip-hammer or any of the pivoted hammers of the cam-disengagement class. The first one is that the face of the hammer will only be parallel to the anvil in one position of the helve. As the helve rotates about a center, a true or parallel blow will be struck only upon a piece of a certain thickness. This is no disadvantage in drawing down, or in taper work, or in work which can be treated across the face of the anvil. But this peculiarity diminishes the adaptability of the hammer for differing classes of work, and it grows worse as the helve is shorter. It can be avoided by raising and lowering the center of motion, but this adjustment can only be limited in amount, on account of the relation between the wipers and the bearing-plate.

Secondly, the limited arc of its motion restricts the applicability of the trip-hammer for deep work or for upsetting. It cannot be made to strike a heavy blow on a large piece, because the weight can fall through but a short distance. But the larger the piece the farther must the effect of the blow penetrate to perfect the welds in the interior, and hence the heavier should the blow be.

Thirdly, the shocks and vibrations of the frame-work and transmissive machinery are a drawback, especially where a large number are driven from one line.

Fourthly, the limits of variation in the intensity of the blows are narrow. A certain minimum cannot be exceeded, which is represented by the weight of the head multiplied by its fall. The maximum intensity is due to this weight together with the impulse due to the rebound. A much wider range is desirable between the first shaping blows and those which should be used to finish the shaped surfaces. But there are certain marked advantages possessed by the trip-hammer. It is cheap in first cost and in foundations. It is adapted for drawing down. Light blows can be delivered with great rapidity. But its special application is found in swage-work between formers. It will hold its own swages on face and anvil, and they can easily be of different diameters and serve as stop-gauges for each other. Hence these hammers will be extensively used for this class of work, and invention and improvement have been in the line of avoiding some of the drawbacks other than those due to the fixed center.

A type of these improvements will be illustrated by Fig. 3. Here, as before, the power is communicated from the line shafting by a belt which may be tightened by a pulley controlled by the treadle which surrounds the anvil. The driving-shaft is, however, no longer a cam-shaft, but carries an eccentric. From the strap of this eccentric a link passes up to an "oscillator," whose center of motion is the fulcrum of the helve. The eccentric is made in two parts. On the shaft is the forged iron eccentric proper, which has a flange upon one side of it. Upon

this eccentric fits a composition eccentric-ring, being secured to the first by tee-bolts, which fit in a slot in the flange. The steel eccentric-strap fits upon the composition ring. It will be seen that by this arrangement the total eccentricity or throw of the oscillator may be varied at will from the sum of the eccentricities of the

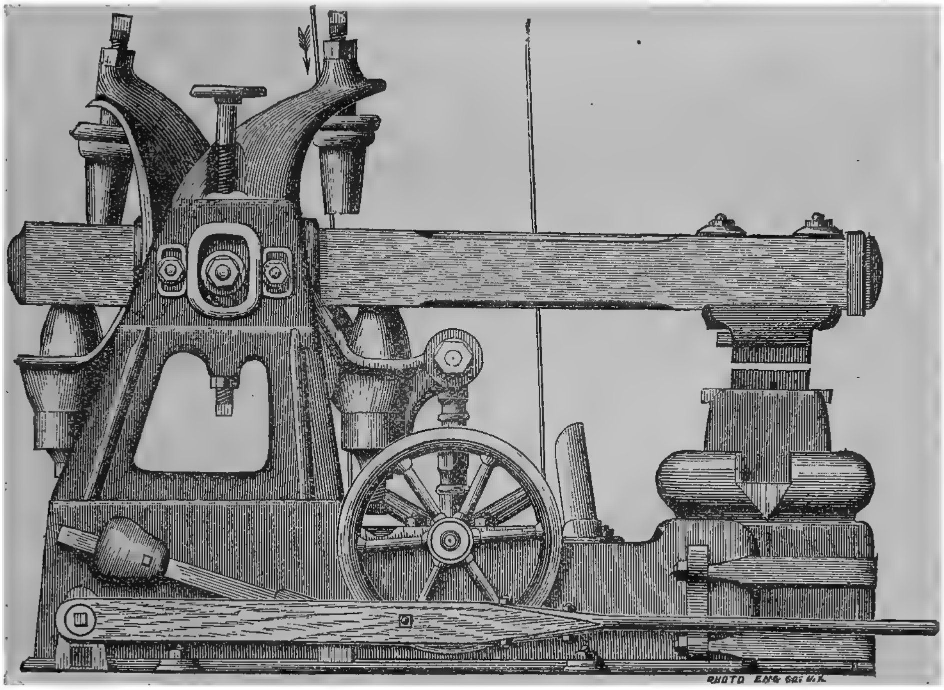


Fig. 3.

two parts to their difference. Hence an adjustable throw is obtained. The link from the eccentric-strap is fitted with a right-and-left sleeve and jam-nuts, so that the height of the hammer may be varied. Between the strap and the oscillator is a double-hinge joint, the pins being at right angles to each other in parallel planes. This prevents any untruth in the dies from making the eccentric-strap heat, because obliged to work out of line. The oscillator transmits its motion to the helve by means of two rubber cushions which are compressed against its under side, and thus alternately lift and force the head. There are two adjustable stationary cushions, secured to the husk above the helve, which arrest the rise and help to start the rise, respectively, without shock to the shaft. The helve is pivoted upon steel pins with jam-nuts, taking into taper steel bushings forced into the trunnion-castings. The pins can be separately raised and lowered by screws in the housings, and by a lateral adjustment the face of the hammer can be brought to coincide with either side of the anvil. The face is bolted to the helve by Norway iron bolts, with leather washers under the nuts to absorb the vibrations. The trunnion-castings are similarly secured. A weighted brake upon the balance-wheel arrests the motion of the shaft when the treadle is released, and the form of the oscillator is such that the hammer will not stop with the dies together. The anvil-block is separate from the bed-plate, being clamped to the front for steadiness only.

It follows from the manner of moving the helve by contact on both sides of its center, and from the use of the rubber cushions, that this hammer can be driven faster than the old style of cam-hammers, of the same size and weight. The cushioned hammers may make blows as rapidly as two hundred per minute, and with an intensity sufficient to heat a small rod to redness. This is admirably suited to keep up a low heat in small steel forging. The separate adjustments of the trunnion-pivots enables any relation of parallelism to exist between the anvil and the face without lining up the dies. The shaft is borne upon the frame and cannot get out of line, the adjustment for different thickness of die being effected by the right-and-left sleeve.

A somewhat similar design, making a specialty of the adjustment for dies of different thickness, is shown by Fig. 4. The trunnions are borne upon large gibbed slides which can be raised and lowered together by the bevel-gear and hand-wheel. As before, the helve is not positively connected to the driving-shaft, but lies between rubber cushions in the oscillating **V**-frame. This frame oscillates around the center of motion of the helve. It is driven by an adjustable eccentric from a shaft which carries the usual fly-wheel and flanged pulley. The loose belt is tightened by the foot-treadle, and the release of the latter applies a brake to arrest the motion. The link is adjustable in length to vary the angle between the anvil and the hammer-face. The shaft is bracketed out from the gibbed slides so as to rise and fall with the trunnions, the slack of the driving-belt being taken up by the tightener.

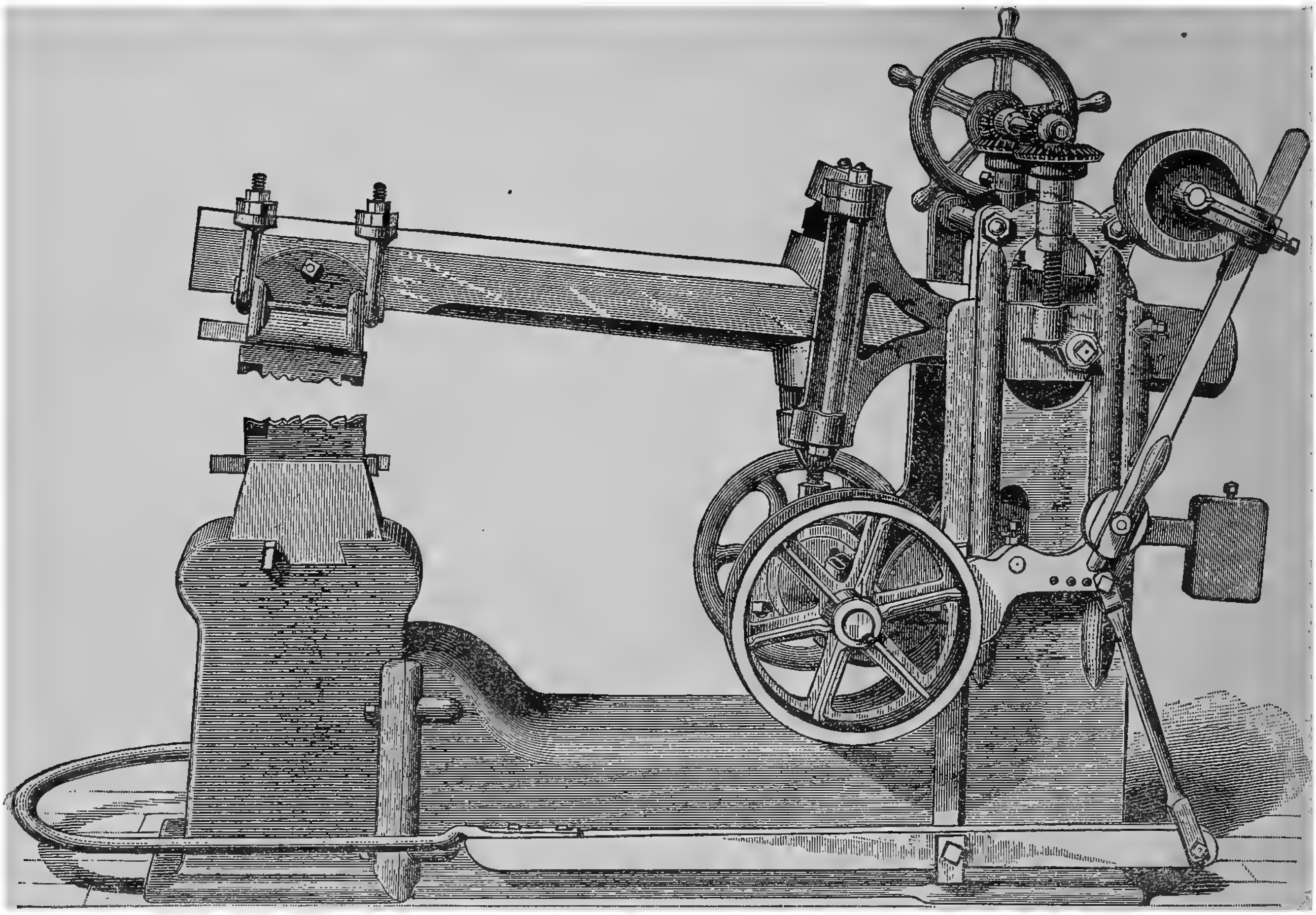


Fig. 4.

It will be seen that in this hammer the adjustment for dies and work of different thicknesses is very easy and rapid, but that considerable shock must be borne by the eccentric-shaft. The use of rubber cushions enables the blows to be delivered quite rapidly.

§ 3.

CRANK-HAMMERS.

The object sought in the design of these hammers is the delivery of a dead-stroke, while the faces of hammer and anvil shall remain parallel for all thicknesses of work. The crank is used to produce the reciprocating motion of the head, either directly or indirectly, and the oscillating helve disappears. It is of course impossible to connect the head directly to the crank-pin. The blow could not then be a dead one, penetrating into the inner particles of the work, but would be an elastic one, affecting the surface only and in part. Moreover, different thicknesses could not be operated on without inconvenient readjustments. It will therefore be found that between the crank-pin and the head there will be interposed springs of some sort. Their effect will be to cause some free motion and to increase the range of the tool and also the force of its blows. The crank is well adapted for this class of motion, inasmuch as it begins the motion of the head by a gradual lift, increasing until half stroke is reached, when the lifting effort slowly diminishes, permitting the inertia of the rising head to slacken the strain on the springs as the crank reverses. On the down-stroke the accelerating crank compresses the spring upon the moving head, giving this extra force to its fall.

One of the hammers of this type is shown by Fig. 5. It is driven by a belt, which may be engaged with the crank-shaft either by a clutch or by a tightener upon the belt running loose. The crank-pin is often made to bolt into a slot in the balanced wrist-plate, so that the stroke of the head may be varied. The head slides between guides on the front, so that it shall always strike a fair blow on the anvil beneath. The connecting-rod, made adjustable in length, carries at its end a clamp for a steel locomotive-spring, whose ends are drawn together by a multiple band of flat leather. The head is hung from the middle of the leather link. It will be seen how the living force of the head will compress the springs on the up-stroke, that compression being given out in the blow. The amount of this compression is controllable by the will of the operator, since it depends entirely upon the speed of

the shaft. The more rapid the rise of the head the greater is the efficiency of the spring. The speed, being controlled by the frictional contact of clutch or tightened belt, is varied by greater or less pressure upon the foot-treadle. The anvil is made a part of the frame, which is left open at the back to permit drawing down across the anvil. Very often the faces of the anvil and head are made T-shaped, so as to act equally well whether work is presented from front or side. Here, again, the interposition of the elastic media permits a large number of blows to be made per minute. The 100-pound hammer, suitable for general forging and die-work, may make from 200 to 250 blows per minute.

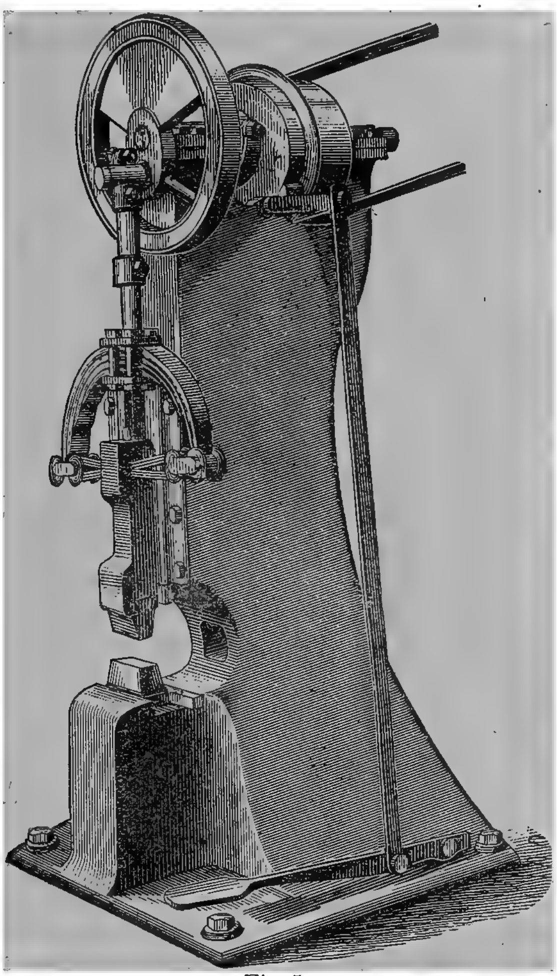


Fig. 5.

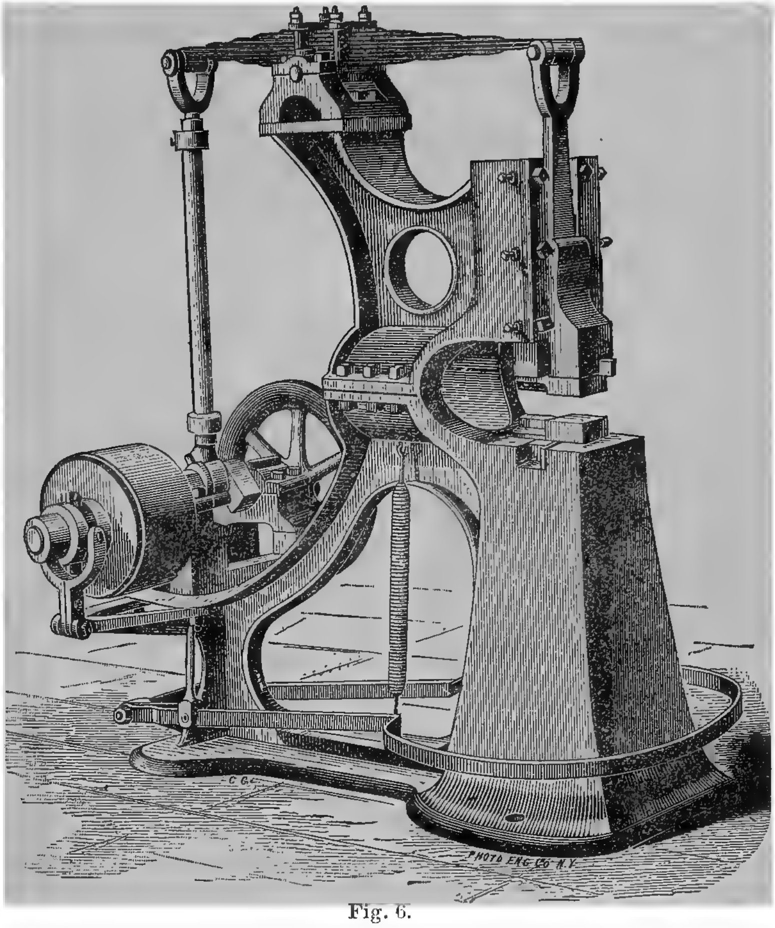


Fig. 6.

A design involving similar principles is illustrated by Fig. 6. Here the crank-shaft, with its friction-clutch, is put lower and nearer the holding-down bolts, and an adjustable connecting-rod causes a spring working-beam to lift and lower the head. The slides are gibbed, and the frame at the rear is made open. It has the same adaptability to machine forging where the depth of the work is being continually varied, and strikes a more or less dead blow.

It were a very natural step to replace the elasticity of a steel spring by the elasticity of a cushion of air and apply it to produce dead blows with a crank-hammer. Such an arrangement is illustrated by Fig. 7. The upper part of the hammer-head is made into a cylinder, truly bored, in which fits a piston, connected by a rod and pitman to the crank-pin. When the pin rises the piston rarefies the air below it, and compresses the air above it. The piston in its rise has uncovered several small ports in the bore of the cylinder, through which air enters below it. The compression of the air has been sufficient between the piston and the top of the cylinder to lift the whole cylinder and head, and the living force of the motion upward will continue after the pin has begun to come down. Hence by compression of the air below the piston will result an increased velocity of fall and greater force of blow than are due to the weight alone. The connection also not being positive, the blow will be a dead one. The crank-shaft, as usual, is driven by a loose belt, engaged by a tightener controllable by the foot. Nearly all have also a brake to arrest the motion quickly. In another design this arrangement is reversed, and the connecting-rod moves the cylinder, while the piston is connected to the head of the hammer.

Another type of crank-forging machinery is shown by Fig. 8. The head is guided between the two uprights, which oblige it to fall so as to strike a fair and dead blow. There is no reinforcement of the weight of the head. The head is lifted by a flat leather belt, which is attached to a pin upon the crank overhead and is a little too long.

The belt is attached to the rotating pin by being clamped to a composition sleeve, S, which takes the wear. As will be seen from Fig. 9, the crank is revolved by the gearing from the belt-wheels, through the ratchet-wheel A and dog *d*. When the drop is up, the crank stands a little forward of its upper dead-center, and is prevented from falling by an arm which strikes against the ratchet-arm R. When this arm is pulled away by pressure upon the treadle below, the drop falls, the dog sliding past the ratchet-teeth, since it moves faster than the latter, and is prevented from clicking by a guard. When the blow is delivered and the ratchet-arm stands up, the dog falls into the ratchet-wheel, and the gear takes hold to lift the drop. The dog stays in gear till the rotation of the arm is stopped as before, or until the weight of the drop pulls the dog out if the treadle is kept down. The lifter-gear is carefully cushioned with rubber disks to absorb shocks, as also are the detents and stops.

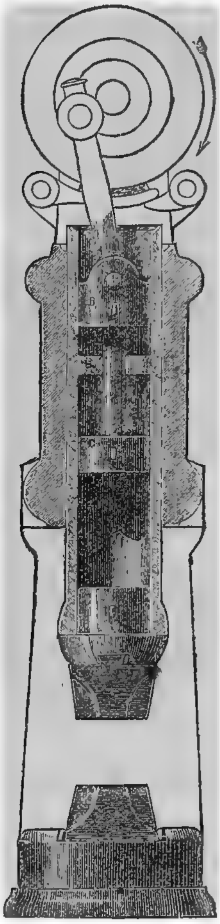


Fig. 7.

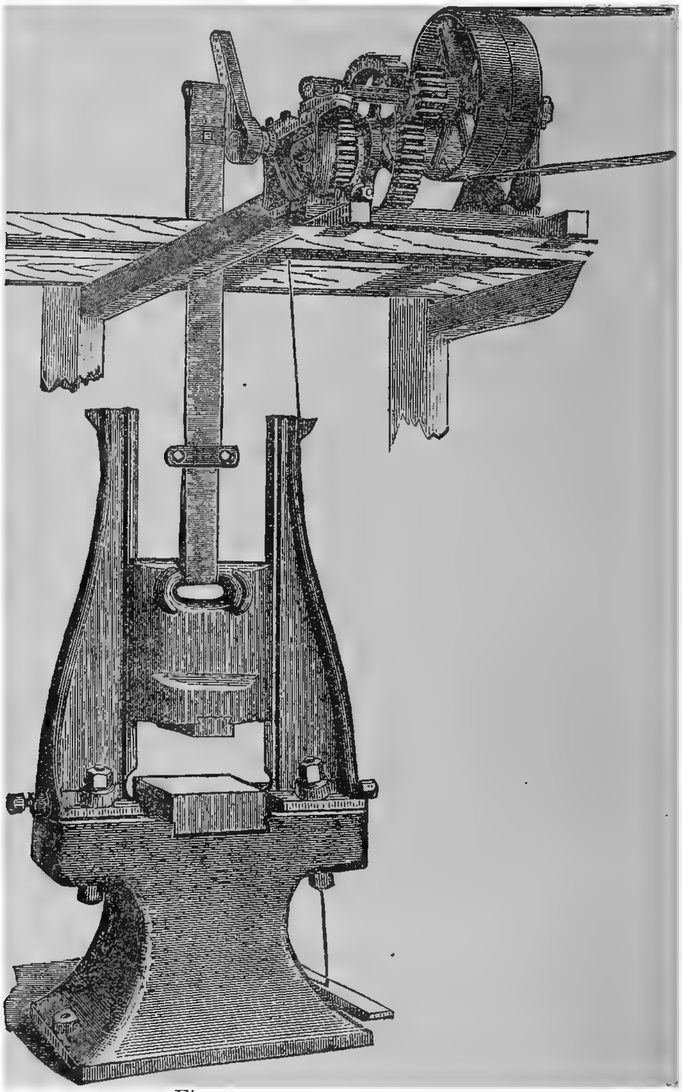


Fig. 8.

This device is admirably adapted for die-forging, and is better for that than for the miscellaneous work of a general forge. It can deliver only from sixty to eighty blows per minute, although they can be heavy and sufficient. It has the advantage of avoiding the necessity of attaching the lifting-gear to the guides, and any settling of the anvil is less annoying or disastrous than in some of the other designs. The flexible yet maintained connection between the drop and the lifting-gear gives an inelastic blow and yet prevents a false blow being given, due to the rebound after the fall of the weight. The length of the lifter-crank is made alterable for different heights of fall, and the uprights are held from spreading by inclining inward the faces of the wings and putting in the holding-down bolts normal to these faces. Lateral adjustment is secured by the set-screws and jam-nuts.

This arrangement has been especially applied for die-forging, when the machine will be called a "drop-press". The process of "drop-forging" depends upon the principle of the flow of metals under strain. A pair of dies is used, each containing one-half of the desired volume. One is secured to the anvil-casting and the other to the face of the drop, so that they shall match when together. The upper die is usually keyed into a dovetail groove in the face of the drop, and the lower one is made to match it by the adjustment of four or six poppet-head screws by

which the die is held. The dies are of refined steel, the form to be produced being milled out on a jigging-machine before the steel is hardened and annealed. When in use, red hot-metal in merchant form is put in the lower die so as not quite to fill it. The upper die is released, to fall and force the metal to fill out the interstices of the dies, both upper and lower, of which of course the reproduction is complete. Wrought iron or ingot steel or cast steel can be treated in this way, and quite complicated forms can be very cheaply, because rapidly, produced. The small carriage hardware, gun, pistol, and sewing-machine forgings, and small tools, such as wrenches and the like, are now made in this way, with an enormous increase in the productiveness of a given establishment and a given gang of men. But one blow is usually necessary to complete the forging, and more are unwise, inasmuch as a "fin" of the superfluous metal is forced into the space between the dies, which thin fin cools rapidly. Any extra blows are borne by this fin and will only deteriorate the dies. This fin being removed by putting the shaped piece between "trimming-dies" in a punching-press, any openings will be punched out, and the finished piece will be sheared off from the bar of which it is a part. Slight treatment with emery-wheels or by heavy pressure in a cold-press will be all that is required to produce a finished article. It will be seen that the crank-lifter is very well adapted for this class of work.

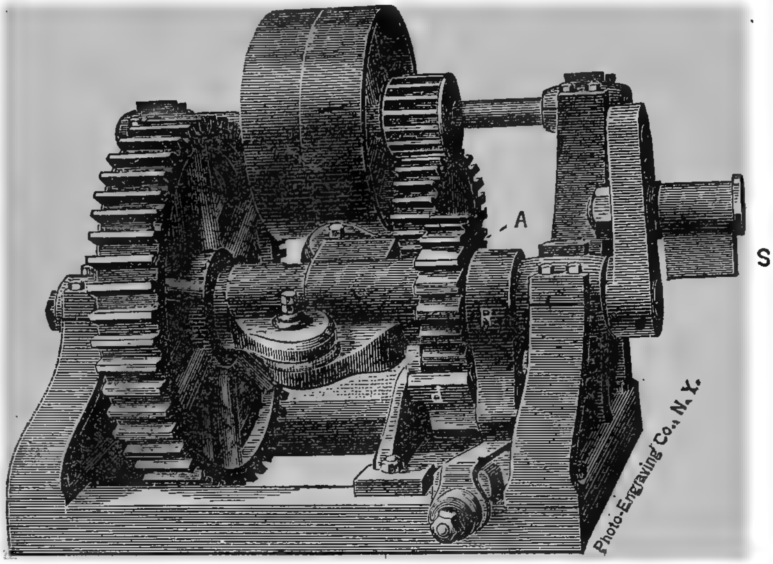


Fig. 9.

§ 4.

FRICTION- OR DROP-HAMMERS.

These hammers have received their special development to meet the requirements of drop-forging. They are adapted to give a small number of blows per minute, by a weight falling through a considerable distance.

The early germ of these hammers is, no doubt, in the old "monkey" hammers. A piece of flat belt-leather passes from the head of the drop over a revolving shaft and down to a weighted handle. The weight of the handle is not sufficient to make the belt seize the shaft, but when the handle is pulled by the forger the normal pressure is sufficient to cause the power to lift the drop. When the handle is released the blow is given. The drop is guided so as to give a true blow.

Hammers somewhat similar are still in use, and successfully. An overhead roller winds up the flat belt when a clutch is engaged. The weight falls when the clutch is released. To prevent shock, the leather is much too long, and a small counterpoise weight on a cord from the roller secures that the belt shall always be rightly wound upon the roller.

If the belt of the early form be replaced by a flat board which can be gripped between two overhead rollers revolving in opposite ways, and which can be released at will, the foundation for the modern friction- or roll-drop hammer is laid. The differences in the different forms will be more in detail than in principle.

In the hammer of Figs. 10 *a* and 10 *b* the two rolls are of cast iron finished smooth and driven in opposite ways by the belt-wheels, which carry one an open and the other a crossed belt. One roll revolves in fixed bearings. The other roll turns in a bearing at each end, which is a cylindrical bushing in the journal-box, the roll-bearing being out of the center of the bushing. It will be seen that if the bushings be revolved through a small angle, the axis of the roll will be displaced laterally, so that the board between the rolls can be released or seized with any desired pressure. The bearings of the fixed roll are made adjustable to compensate for different thicknesses of board and for wear, and to keep the board always vertical. The movable roll is released from the board by the rise of a rod, D, which is connected with loose joints to the foot-treadle, so that the weight of the rod acts to keep the rolls together. Upon the rod D is a chock, which, when struck by the drop in its rise, will lift the rod and release the board, while at the same instant the bent lever-latch on the other side of the head drops in place to keep it from falling. The head therefore remains in place until the treadle is depressed; when the latch is withdrawn the rolls are kept apart, and the head falls. The latch is adjustable on the guides to vary the fall by steps of 6 inches, and the treadle and latch are kept up by a spiral spring or by a weight. The lifter-rod D is made to connect to the

treadle by contact-joints so that the rising of the chock need not jar the treadle. A turn-buckle is put in this linkage so as to adjust the relation between the treadle and the rod D without interfering with the latch on the other side, and to permit a rapid series of blows with uniform force without full motion of the treadle.

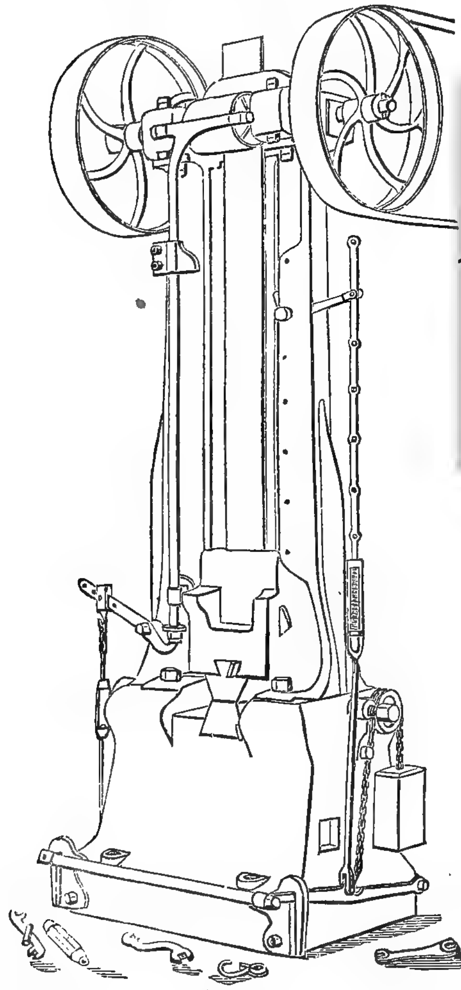


Fig. 10 *a*.

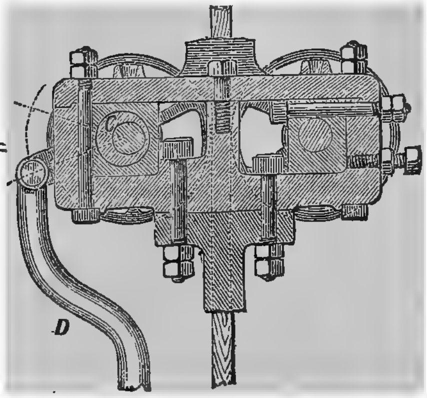


Fig. 10 *b*.

The next type of hammer has the two rolls geared at each end, one only being driven by one or two belt-pulleys (Fig. 11). The teeth are of involute profile so as to work equally well at different center distances. The movable roll is hung in bearings on a swinging yoke, which is pulled over by a crank-lever acting upon a cam, the lifting-rod being moved from the treadle as before. There is the similar latch-gear on the right-hand side, automatic and adjustable. An automatic trip-gear may be added if a series of uniform blows should ever be called for.

The hammer of Fig. 12 has the two rolls geared together and brought together by eccentric mounting, as before. The contact is maintained by the weight of the lifting-rod D (Fig. 13), reinforced by a spiral spring. As the hammer rises it strikes a dog on the rod, opening the rolls and releasing the board. Since the lifting-rod is not attached to the treadle, as in the former designs, the release of the dog as the hammer falls would close the rolls and stop the fall. To prevent this a switch springs in under the end of the rod, holding it up and keeping the rolls apart. The head has a curved plane on it, which forces out the switch from under the rod when the blow has been delivered, lowering the rod and causing the rolls to lift again. This switch is pivoted upon an eccentric mounting to take account of varying thickness of die or work. The dog-rod can also be worked by hand-lever at side of frame or by a small treadle. The foot-treadle operates a lever overhead attached to a pair of toggle-levers which grip the board on its descent except when held away by the depression of the treadle. If the treadle be held down a number of uniform blows will be struck, which especially adapts this arrangement for certain classes of work. For miscellaneous work and blows of varying intensity the adjustment of the other types gives the operator more freedom in the use of his hands. The toggle-joints are upon eccentric bearings, which let the board slip through them on the up-stroke (Fig. 13), but which hold it when its motion reverses. All such friction contact bearings are made adjustable to compensate for wear and variations in thickness.

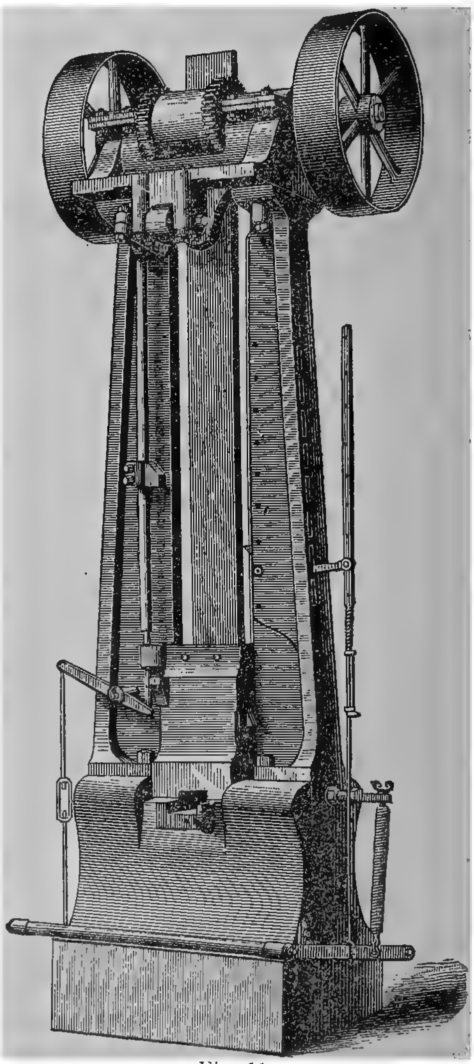


Fig. 11.

All the hammers of this friction-roll type are open to the objection that the rolls when brought together demand that the drop shall start from rest and acquire at once the full speed of its lift. There must therefore be a slip somewhere while the inertia of the head is being overcome. If this slip occurs in the driving-belts they will wear or burn. If it occurs between the board and the rolls the former will become worn into a hollow at the point of first seizure and the rolls will fail to grip at that point. But the board of white oak or hickory is as apt to deteriorate from other causes, and the general adoption of this class of hammer for drop-forging is proof of the satisfaction it has given in that class of work. They do work which could only be done otherwise by heavy steam-hammers, which would involve

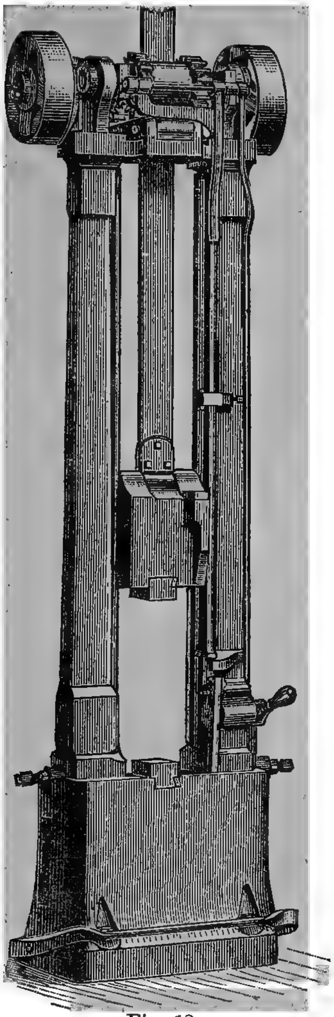


Fig. 12.

great outlay and expensive accessories and give but a limited production. A battery of these hammers can be set up in one establishment and its capacity can become almost unlimited. Ordinary labor can handle them, and but one man is required. In one of the shops for fire-arm manufacture a special type of drop-hammer is in use. A square central pillar has pawls on its four faces and is made to reciprocate vertically. Four guided drops are lifted by each rise and are held from falling by pawls. The release of the pawl of any head, at the will of the operator, permits the head to fall. The heads weigh 500 to 800 pounds, and may fall 30 feet.

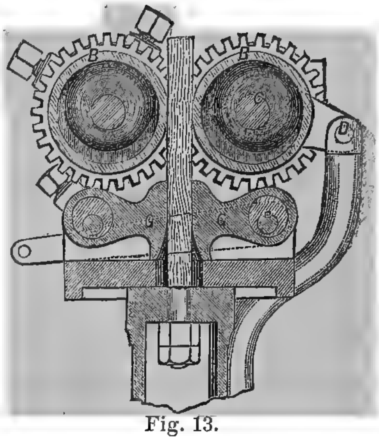


Fig. 13.

§ 5.

STEAM-HAMMERS.

In this class of hammers the power of the steam from the boiler is applied directly instead of indirectly through the engine and shafting of the shop. They form, therefore, a class distinct from the power-hammers previously discussed.

The hammers of the pivoted type directly driven by steam present themselves first. In these the large wooden helve is pivoted upon trunnions, and just in front of the husk is put a steam-cylinder of large diameter and short stroke, below the floor level (Fig. 14). This cylinder is usually single acting, lifting the helve, and letting it fall by its own weight. The rise is arrested by a wooden spring buffer beam at the tail of the helve. The valve admitting steam to the cylinder is a plain slide-valve, worked from the cross-head, or is in the form shown in the cut, a rotary sliding valve. In the form shown in the cut, the rotating valve is balanced by being hung by a brass ring and bolt from a plate of flexible copper or steel in the bonnet of calculated area sufficient to keep the valve from bearing too hard upon the seat with the given working pressure. In the older forms, worked by an arm from the cross-head which struck tappets upon the valve-stem, the difficulty was due to the shocks against the tappets. The valve-stem had a stout thread cut on it, and these two tappets could be separated or brought together for work of different thickness and for different heights of fall. But as the slide-valve was unbalanced, it took considerable power to move it, and the cross-head arms and the valve-stems were continually breaking and becoming battered. Other arrangements for admitting steam were by the use of a cock-valve, which was revolved upon its axis by the cross-head arm which struck tappets having inclined faces, and displaced them around their axis. And again the cross-head arm acted upon two inclined planes in slots in a plate, the planes being adjustable in position at the will of the operator. In the form shown, while the adjustable tappet hand-nuts are retained, yet the valve moves so easily that the gear is not worn out. The valve-seat is near the bottom of the cylinder, permitting the use of a short steam-passage, with long narrow port, and giving a decisive sharp blow. The position of the port for exhausting also enables the condensed water to drain out easily and quickly, and lets the hammer fall easily upon the work. The speed at which the hammer may be driven adapts it for several classes of forging, and it can be applied for billeting and faggoting. In one case where so applied the helve is a box girder of ingot-steel plate. It has the advantages for swage- and die-work possessed by every helve hammer, but also has their limitations.

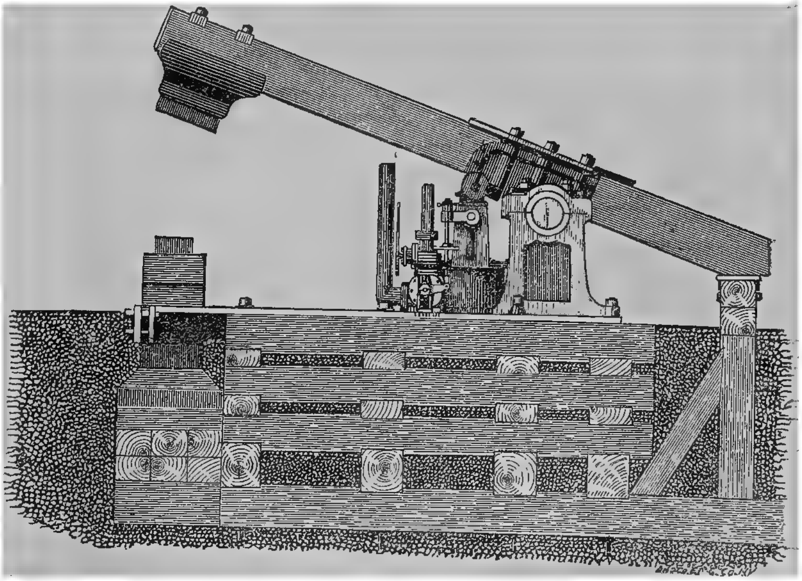


Fig. 14.

To a similar type belongs the steam-striker in limited use in forges. A steam-cylinder of short stroke has its rod connected to the short arm of a rock-shaft. At right angles to this arm is a second arm much longer, on whose

end is the hammer-head. A small motion of the short arm, caused by admitting steam into the cylinder, brings the head down with high velocity upon the work between itself and the anvil. The rock-shaft bearings are so adjustable, relative to the cylinder, as to enable the plane of the sledge-stroke to be carried round through 180°.

The direct-acting steam-hammer consists essentially of a vertical steam-cylinder, in which plays the piston actuated by the steam. Upon the end of the piston-rod is the hammer-head, which strikes the work as it rests on the anvil below. The head may either be lifted by the steam and allowed to fall by its own weight, or extra force may be given to the blow by admitting steam above the piston-head. The cylinder will be carried and the head will be guided by the frame, and the admission and exhaust of the steam will be controlled by suitable valve-gearing.

This type of hammer has very marked advantages. Such are the simplicity of its mechanism, the elastic connection between the head and the driving power, and between the head and the frame; the absolute controllability of the blows, in frequency, in power, and in height; the saving of expense of power when the hammer is not in use, and the avoidance of useless wear of belts; and lastly, the economy which results from putting the hammers where they are wanted, without regard to the conditions imposed by transmissive machinery. There may be a small loss from condensation in the steam-pipe, but careful lagging will reduce this to a minimum. Then, further, the direct-acting steam-hammers are adaptable to all classes of work. Plain forging, die-forging, drop-work, upsetting, etc., can all be done upon the one tool without necessitating any change, except in the dies. The work can be presented in any direction, the space around the anvil being open on nine-tenths of the circumference. A number of swages can not be held at once, as in helve-hammers, lest the blows be delivered out of the axial line of the rod.

Steam-hammers are made with single or double frame, according to their weight. The lighter hammers have but one upright (Fig. 22), consisting of a curved post of round or rectangular cored section, supporting the cylinder at the top. The anvil is carried upon a separate post, which passes down through the sole-plate of the upright. The anvil and tup or head are usually put oblique to the plane of symmetry through the upright, so as to enable the smith to present his work fairly either across or along them for drawing down and finishing. The larger hammers have two uprights, giving rise to what has been called the A-frame. Two uprights are bolted to the foundation, one on each side of the anvil, of such a shape as to guide the head by their upper parts in some designs, while the cylinder is cast upon an entablature to which the uprights are bolted. In other designs the piston-rod guides the head and the uprights are of different shape, to give greater room around the anvil and between the frames. Where the shape is such as to give little room between the uprights around the anvil, the latter is either set obliquely or else the legs are spread sidewise, so as to separate each into two and to leave a passage through each. The object of these two arrangements is to enable the forger to hold chisels and fullers at right angles to the work, and to enable him to see it without deceptive fore-shortening.

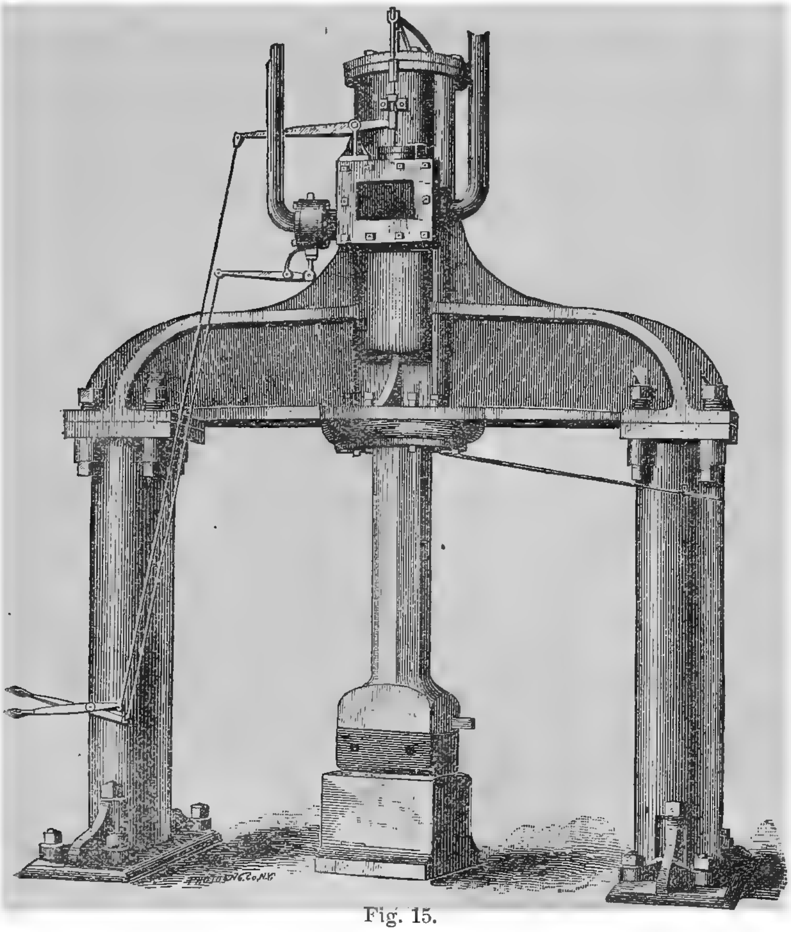


Fig. 15.

To give free room around the anvil the "high-frame" hammer has been made (Fig. 15). The frame consists of two vertical pillars surmounted by an entablature, upon which is secured the cylinder. In this the anvil is set oblique to the plane through the pillars.

The uprights of double-frame hammers are usually bolted and keyed between lugs upon a sole-plate which envelops the anvil-pier (Fig. 16). This sole-plate is bolted by long holding-down bolts to foundation piers of masonry or brick, one at each end, having considerable lateral spread at the bottom to distribute the pressure over a large surface. On marshy ground it will probably be necessary to drive down piles first and cover them with a timber crib-work, around which concrete is rammed. For the lighter hammers the piers may be of cob-work timbers, filled in with concrete. In either case the piers are surmounted with a thickness of timber, perhaps of 3-inch plank, and on this the sole-plate is bolted and trued. The anvil-pier is similarly built, with lateral spread to distribute the blows, but the three or

four courses below the anvil-plate will be of heavy timbers bolted together. Between lugs on this plate will be keyed the anvil-block, which again will receive the die in a dovetail groove in its top. In the lighter hammers the anvil may be all in one piece, and rest upon a flat pier of timber passing down through the foundation of the frames. In the single-frame hammers the arrangement will differ only in depth of foundation and in the permissible use of timber (Fig. 17). It is a very usual and excellent plan to use jam-nuts on the foundation-bolts, that they may not become loosened by the vibrations.

A primary difference in different designs of hammers arises from the methods of guiding the head. In the first designs the steam only lifted the piston and head. Hence a small rod was used, and the weight of metal for the blow was put in the head or ram. Therefore it was necessary that it should move between guides in the uprights, to avoid flexing the light rod. In the later designs of the Morison and high-frame hammer the weight for the drop was put into the rod, so that the increased section made it possible to guide the lower end from the cylinder above. This left, of course, a much higher opening around the anvil, but made it necessary to have some arrangement to prevent the rod and die from turning. In the high-frame hammer the rod is made polygonal, and plays through a polygonal stuffing-box (Fig. 18). In the Morison hammer the bar is prevented from turning by the grooves on opposite sides of its upper prolongation which work the valve.

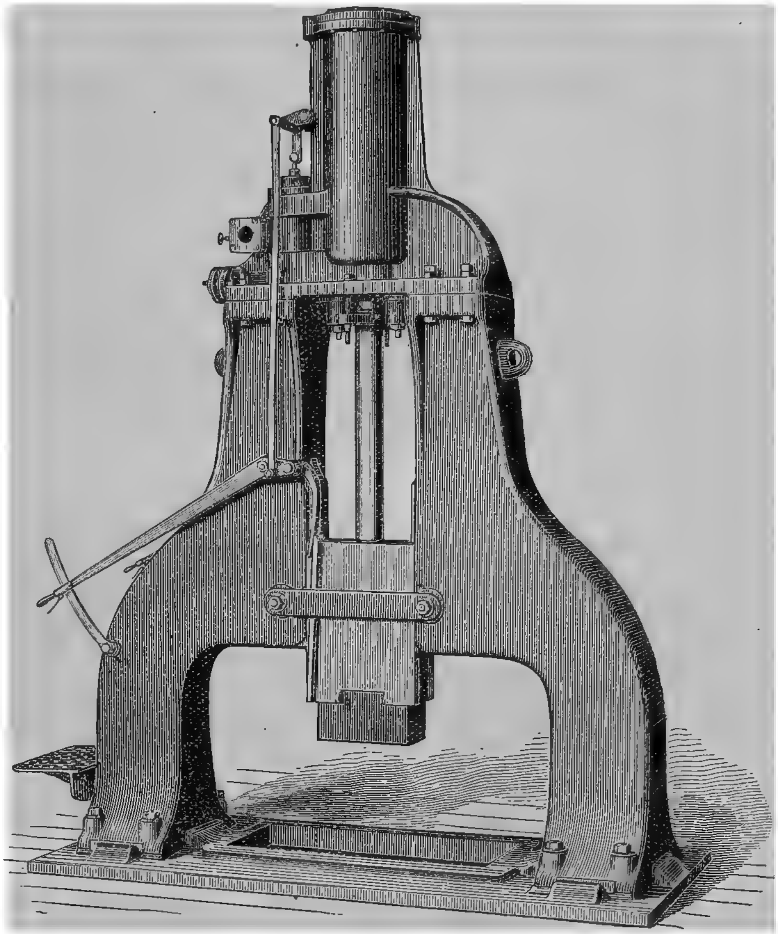
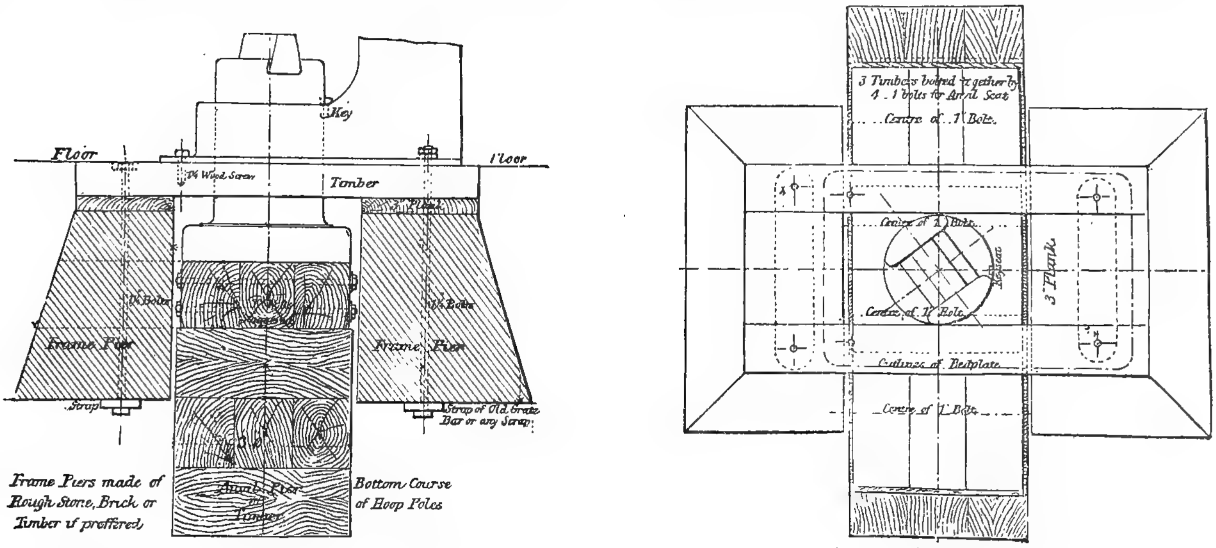


Fig. 16.

The difficulty connected with the guiding by the rod from the cylinder, is that any blows reacting upon the rod outside of its center line tend to force it to one side and cause the stuffing-boxes to leak and wear, even with the increase of bearing surface. The prevalent design of to-day will be seen to favor the other system, even with its drawbacks.

The second difference will be in the actuation of the valve which distributes steam to the cylinder. The valve motion for a steam-hammer presents certain distinctive features. It is desirable that the valve be moved automatically by the hammer, at least in the smaller forms; but the attainment of this end is beset with two difficulties. In the first place, the stroke of the piston needs to be cushioned by steam on the up-stroke, but must



SECTIONAL SIDE VIEW. PLAN.

Fig. 17.

not be so cushioned on the down-stroke. If the blow be cushioned by steam, only part of the force of impact is received by the work. Most of it, in fact, is taken up by the steam-cushion, and the hammer loses at least 50 per cent. of its efficiency. Moreover, dead blows are more potent to change the shape and effect the welds in the interior of the piece than elastic blows. If the reaction of the particles from the blow is not resisted by the weight of the ram upon them, the effect of any blow will be confined to the surfaces only. On the up-stroke, however, there must be a steam-cushion to arrest the piston, else the upper cylinder-head will be knocked out. The valve must have steam lead for the down-stroke, but none for the up-stroke; or, in other words, the valve must open the lower port after the hammer has come to rest. Fig. 18 shows how this steam lead is secured in hand-worked hammers. The rise of the piston strikes a stem which insures the preopening of the upper steam-port, even at the peril of the operator.

The second difficulty about automatic gear arises from the fact that the hammer is to forge pieces of varying thickness. When a piece is to be drawn down, it is much thicker when the first blows are given than it is when it is being finished. Moreover, the hammer may be called on to work a thin flat just after a job of upsetting, so that the valve-gear must act with equal ease for a long or for a short stroke at the lower or upper part of the travel of the ram. This second difficulty is overcome by having the lever to which the valve-stem is attached pivoted to a stud which is not fast to the frame of the hammer. This pivot-stud is upon the end of the short arm of a bent

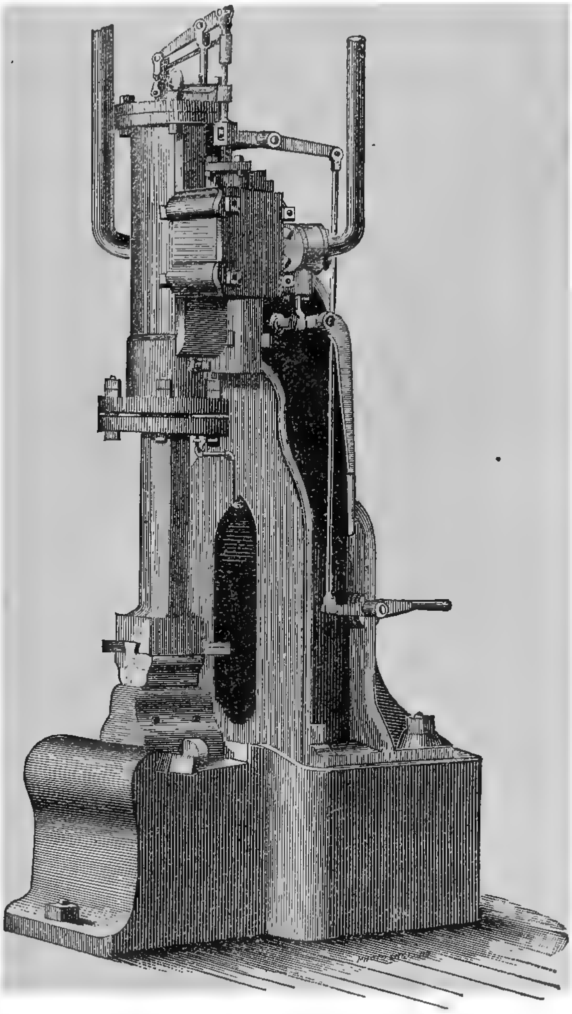


Fig. 18.

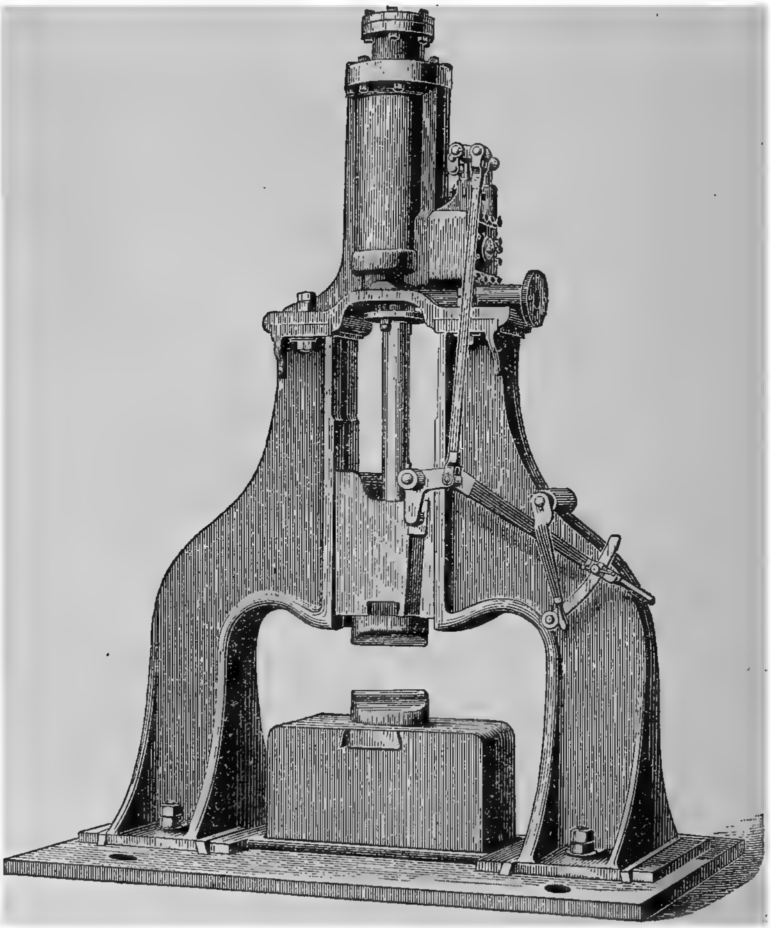


Fig. 19.

lever which turns around a fixed center. This lever is called the working-lever. The long arm ends in a handle, and can be held in any desired position, on a sector near the free end, either by a latch or by a set-screw. The stroke of the ram being so much greater than that of the valve, the arm to the valve-stem will always be shorter than that to the ram, on the floating lever, and therefore a small adjustment of the floating pivot will bring the valve into the proper relation with any part of the length of the stroke.

The overcoming of the first difficulty follows very simply after the second one is provided for. It is accomplished by means of a swinging curved wiper-bar, centered upon the short end of the working-bar in prevailing practice. A short arm at right angles to the plane of the face of the wiper is connected to the valve.

An inclined plane is formed upon one face of the head, and this wiper is held to contact with this plane by the weight of the valve acting upon the short arm of the wiper. When steam drives the hammer down it falls faster than if gravity alone acted on it. Gravity alone acts upon the valve. Hence the descending ram will get away

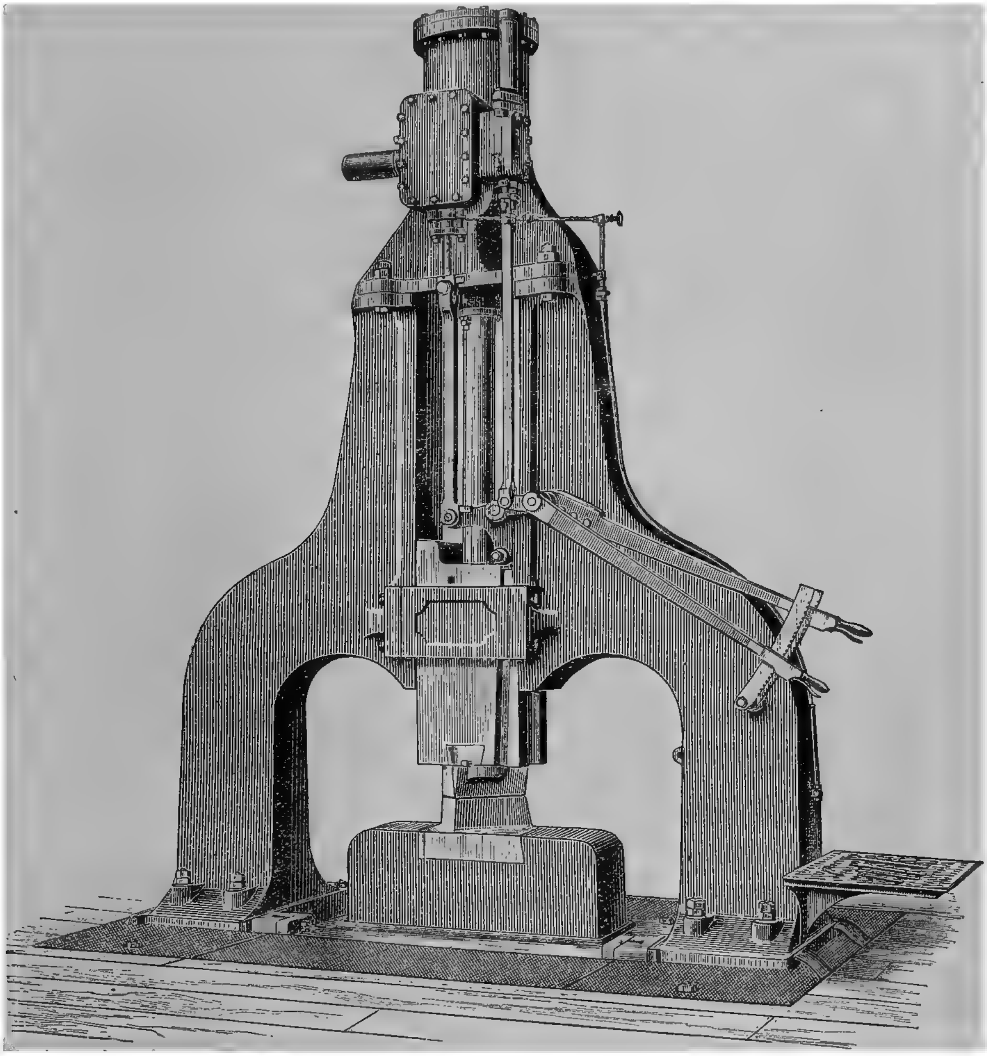


Fig. 20.

from the wiper, which will swing into contact after the hammer has stopped, and properly open the valve. A dead blow will thus be given without steam-cushion. Upon the up-stroke the head and valve move together, and steam lead may be always secured to cushion the rise, or it may be effected by exhaust compression. By handling the working-lever dead blows may be given by the ram as a drop. The working-lever must pull the wiper away, as the two contact surfaces fall at the same rate because acted on by equal forces. Of course, for this gear, the valve must be balanced so as to fall easily under steam. For rapid work the weight may be helped by a spring, or for slow work it may be retarded by artificial friction or by counterpoises.

In the Sellers hammer the connection is positive or maintained between ram and valve, but the coincident motion of the working-lever with the blow retards the admission till after the blow is delivered.

Large hammers are usually worked by hand; but inasmuch as the stroke of these larger valves requires more motion of the working-lever a compound motion is often applied. A groove in the ram moves the long arm of a bell-crank lever, whose short arm is connected to the valve-stem, and whose pivot is on the working-lever as in the previous cases (Figs. 19 and 20). Very many of the largest blooming-hammers are worked directly from the handle, independent of the ram (Fig. 27). In the Miles hammer, shown in section in Fig. 21, the valve is a hollow piston-valve, taking steam from the inner edges and exhausting at the ends and through the middle. The hollow valve permits very short passages, and the position of the exhaust-chamber causes all water of condensation to be carried away from the cylinder even without drip-cocks. The valve-rod needs no stuffing-box with its attendant friction, since it works in exhaust steam only. The piston-rod is tapered into ram and piston, and the piston is packed by steel rings. The head is guided by flat guides with a projecting lip for holding it sidewise, or in some

of the smaller sizes the head is planed with V-grooves. An adjustable gib is also used to take up lost motion and wear by inclined planes controlled by a screw. To avoid the danger from "hammering upward", buffer-springs are put below the cylinder, consisting of compound volute car-springs (Fig. 22). These react against the ram and

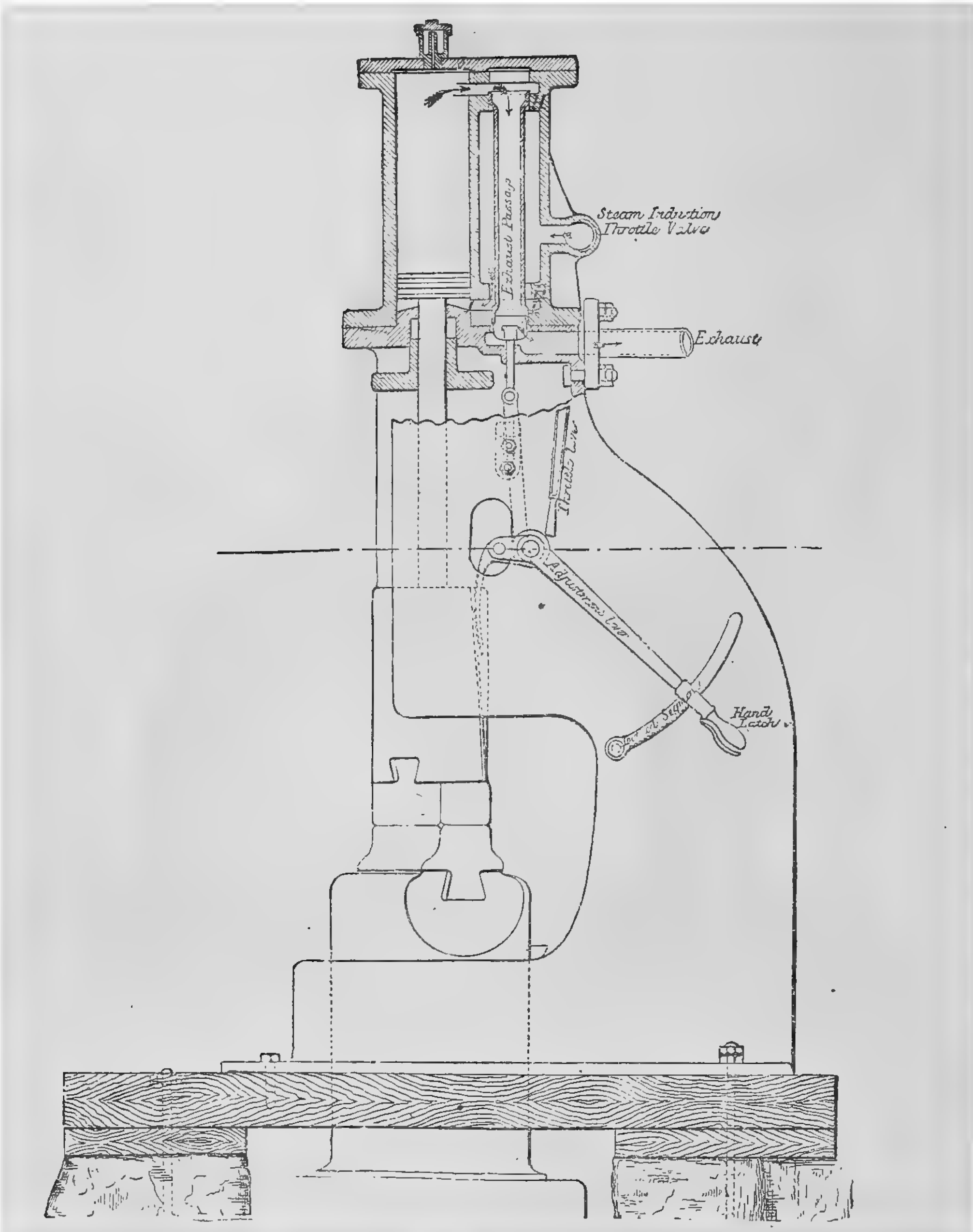


Fig. 21.

prevent injury to the upper cover. The rod is made long enough to permit the piston to protrude through the top of the cylinder when all buffers and the stuffing-box packing are removed. This allows the inspection or renewal of piston-packing without disconnecting the parts.

Fig. 16 shows the larger size, and Fig. 23 shows an especial arrangement for drop-work. The throttle-valve is connected to the dangler by a screw connection, so that the degree of force of any single blow or of any series of automatic blows can be governed by a foot-treadle and the hands of the operator be free for his work.

The throttle-valve for the hammers is the Davis sliding valve of the Corliss type, working in a jacketed casing. The pipes are connected to the hammer by expansion joints, to avoid leaky connections. The openings are arranged so to face as to permit free approach of cranes on both sides.

The Bement hammer (Fig. 24 and Fig. 20) differs in the use of a flat gridiron slide-valve, balanced by means of a shield which slides on a surface opposite to that of the valve-seat. The dangler also is made longer. The piston is cushioned to prevent overstroke by closing over the exhaust passage, which is not at the extreme top of the cylinder. In small hammers the piston and rod are made of one forging. In the larger sizes the rod is slightly tapered and headed over cold. Steel packing-rings are used.

The Morgan and Williams hammer (Fig. 25) uses a square piston-valve. The back and sides of the valve are protected from steam pressure by a hollow trough casting, with ports in the inside of the trough which match the ports in the seat, and are separated in the hollow part by partitions. Steam therefore enters the passages both through the seat-ports and also through those in the shield when opened by the valve. The valve and shield are faced off together upon their lower sides, and the valve is afterward relieved enough to slide under it when the shield is forced to the seat. It is held in place by one or more set-screws in the bonnet of the chest.

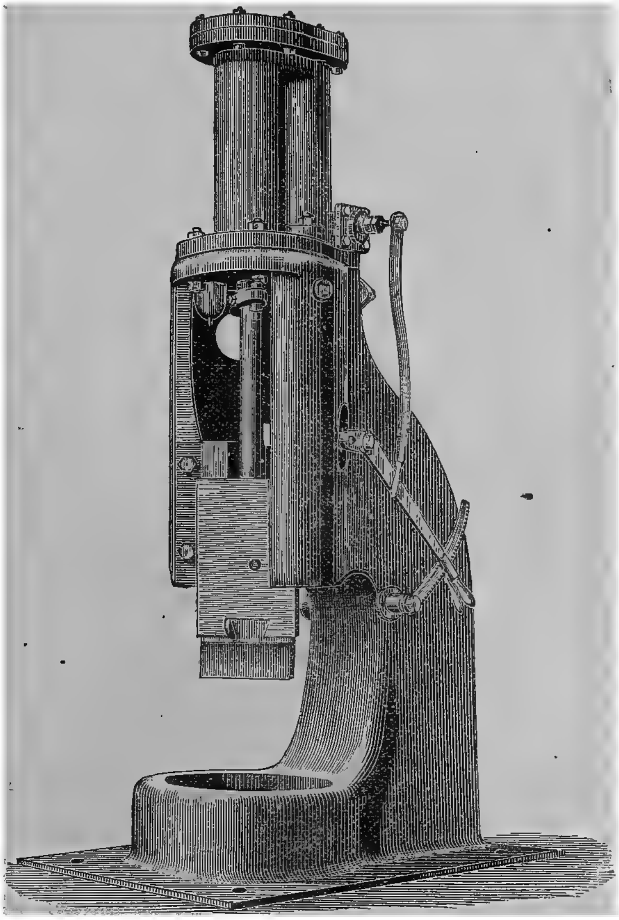


Fig. 22.

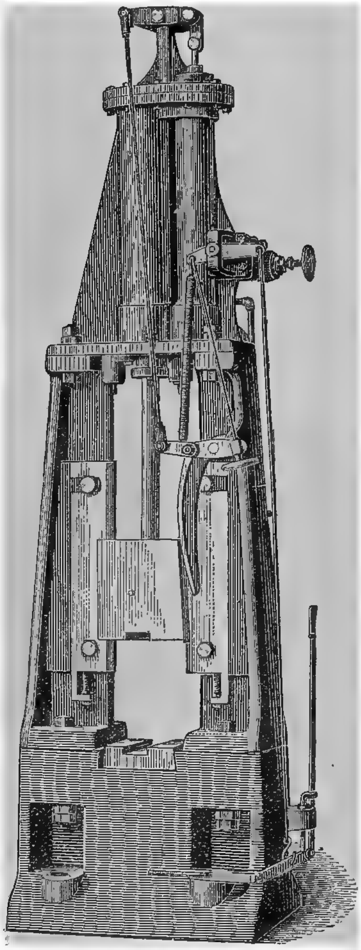


Fig. 23.

For hammers for working steel, which must be handled at high speed, two valves are used, one for steam above the piston and one for steam below, with separate throttle-valve for each chest.

To protect the upper cover of the cylinder, a small cylinder on top contains a volute buffer-spring, whose spindle takes the blow, and should breakage be unavoidable it is the small weaker cylinder which is most sure to go rather than some more expensive part. Ramsbottom's steel piston-rings are used for packing. The rod is fitted as in the Miles hammer with a simple taper fit into the ram. The shocks of impact keep this joint perfect, making it tighter at every blow. The piston is forged on the rod in small hammers. In the larger sizes it is shrunk on and headed over. In place of the dangler or wiper, the valve is moved by a square inclined groove or ridge upon the side of the ram. This controls a bell-crank connected to the valve, the crank being pivoted upon the working-lever. Their drop-hammers have an equalizing pipe on the Cornish system to prevent the necessity of admitting air to the cylinders on the descent. They can be made controllable by the foot of the operator.

In the Sellers hammer (Fig. 26) the ram, rod, and piston are in one forging. The rod is prolonged above the piston to serve to guide the end of the rod by the upper cylinder head as there is no ram guided between slides as in the previous designs. The lower part of the rod is made larger than the upper part above the piston in order that the mass of metal may be greatest near the point of impact. To this large bar is attached the hammer-head proper by means of a circular key and to the head are keyed the dies. For keying the dies a crimped key is preferred, which holds the die with elastic pressure. The key can be bent anew when loosened by use.

The valve-gear is worked by an obvious system of levers, to which motion is imparted from a brass yoke interior to the cap which protects the upper rod. This rod has two opposite diagonal grooves in it, in which fit brass keys attached to the yoke. The up-and-down motion of the rod causes transverse reciprocation of the yoke,

which motion is carried out to the valve-levers through the stuffing-box at the back. The pivot for the lever attached to the valve-stem floats from the end of the working-lever. The valve-yoke also serves to keep the hammer-bar from turning round. In addition to this ordinary gear a supplemental valve is introduced, which controls, by hand, the exhaust from the lower port, without interfering with the upper port. This enables quick, but light-cushioned blows to be struck for finishing, the operator being able to gauge their intensity by the completeness of his exhaust-cushion below the piston. The speed of rise is not affected, and the confined steam below expands upon the up-stroke.

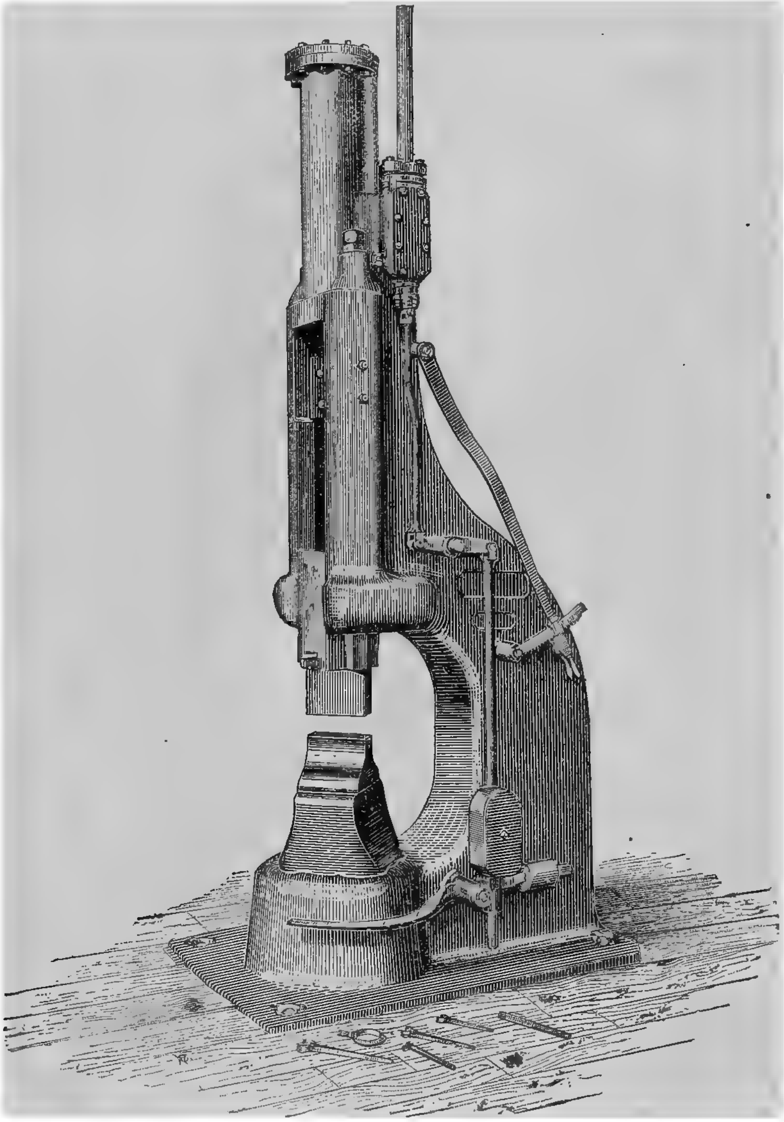


Fig. 24.

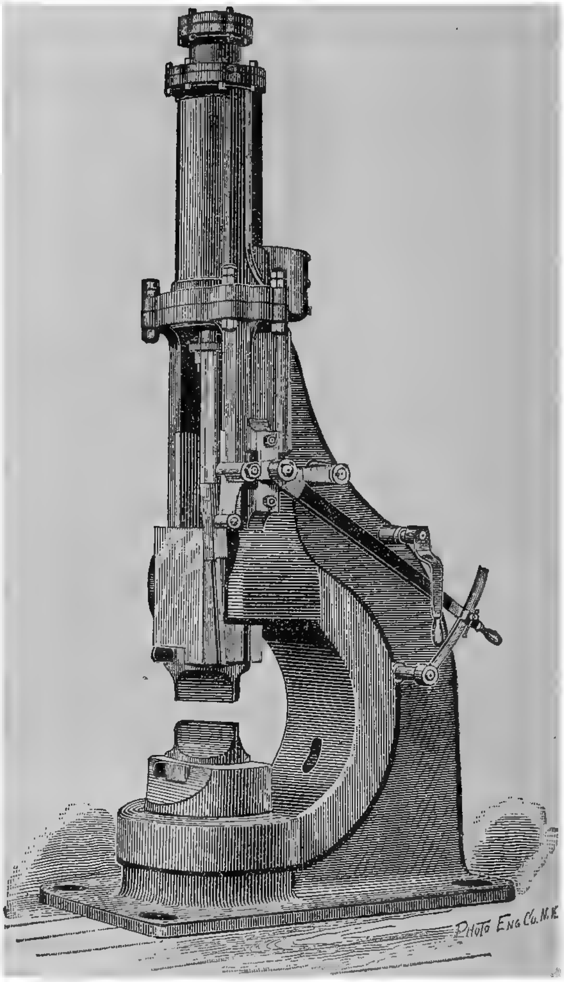


Fig. 25.

The advantage of this system is the free height between the anvil and the end of the hammer-bar. The cylinder also serves, in double-frame hammers (Fig. 27), to brace the uprights at the top. The anvil in these designs is made of five, seven, or eight times the weight of the hammer-bar and accessories. The other designers prefer a relation of one of hammer to ten of anvil.

The simplicity of the construction and mechanism of the steam-hammers of to-day seems to leave but little to be desired. They can be made to deliver elastic or dead blows at the will of the operator, and can be used as drop-hammers. They are therefore fitted for any class of work. They are rapidly displacing all other forms for certain duties, and even in shops driven by water-power they are finding their way. Where power is otherwise running to waste they may be driven by compressed air without losing many of their advantages.

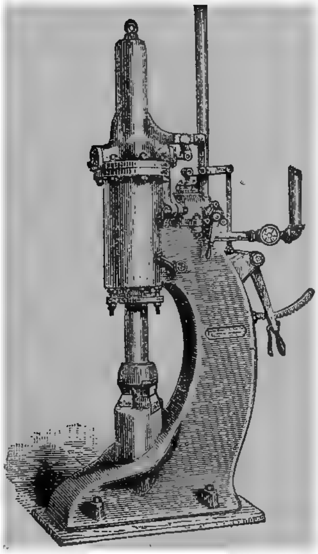


Fig. 26.

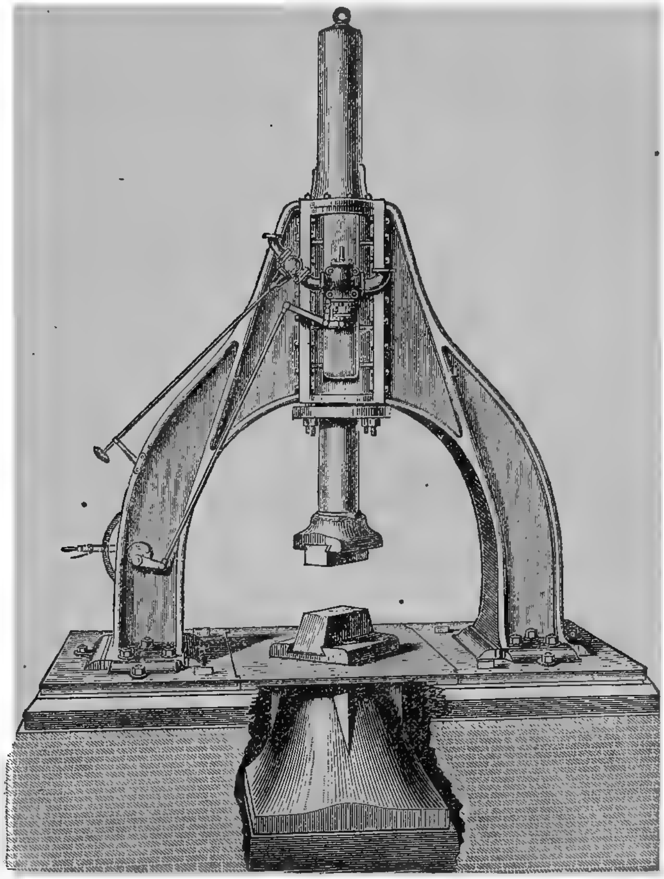


Fig. 27.

§ 6.

RIVETERS.

The next class of tools acting by compression are the riveting-machines. They act to compress and upset the metal of red-hot rivets in the holes of a lap-seam of plate-iron. They also form a head upon each end of the rivet, which bind the joint together by the shrinking of the shank as it cools.

Riveting-machines are of four classes: Power-riveters, steam-riveters, air-riveters, and water-riveters.

The essential parts of a riveting-machine are, first, a stationary stiff post or bolster, which shall serve as an abutment or anvil for the upsetting of the rivet. This bolster carries a stationary die or swage on one side, near the top. The second essential part is a movable guided ram with a die in its end, which shall slide forward and compress the rivet between the moving and fixed dies. This will form the two heads and upset the shank into the holes of the plate so as completely to fill them. The third essential part is the gearing and apparatus for driving and retracting the movable ram. The first two parts must be common to all designs. The variations will be in the driving mechanism. The problem is the gradual exertion of great power through a short stroke.

The power-riveters receive their motion through a belt from the transmissive machinery of the shop. Probably the earliest forms were those in which the ram received its alternate motion from a crank. The rotation of the crank, driven by reducing-gearing from the belt-wheel, forced the die to compress the rivet until the crank came in line with the connecting-rod to the ram. This compression was of great power, since the crank and rod made an elbow-joint as they came into line, although the two links were of unequal length. The special difficulty of this system is that all the reaction of the compression has to be absorbed in rubbing surfaces, on the crank-pin and on the shaft-journals. These, of course, had to be of extra size and all parts had to be of extra weight if excessive wear were to be avoided. To meet this difficulty another form of machine was devised, in which the ram is forced out by a true elbow-joint. When the ram is back, the two links hang down in the form of an obtuse V. The center joint is raised and the links are thus straightened out into line by a cam revolving on a shaft below the links and driven by reducing-gearing, as before, from a belt-wheel. In both forms the gearing to drive the ram is engaged at will by a jaw-clutch. This elbow-joint form has several advantages over the crank-form. The strain is borne by the rigid back of the machine frame on large pin joints. The crank-machine had always to be disengaged when the crank was in one position, with the ram drawn back; the cam-riveter causes the ram to retire by the weight of

the links as soon as released by the cam. The cam moreover may be so designed as to maintain pressure upon the rivet until it cools somewhat under the strain. This was inconvenient and difficult, if not impossible, with the crank-form. It is riveting by dead blows, which is impossible with a maintained connection between ram and driving power. Both tools have the advantage of giving a gradual compression to the rivet, which is most favorable for the flowing of the metal which is to fill the holes. They have, however, the disadvantage of being non-adjustable either in length or in force of stroke. For rivets of different lengths in plates of different thicknesses the only adjustment is by changing the swage-dies for others of different length. This is inconvenient and takes time. The effect of excessive compression is either to fray out the edges of the rivet-heads, permitting access of corrosives to plate and shank, or else a film of the rivet opens the lap-joint by squeezing in between the two plates. Finally, the frame of the machine has to be very heavy and deep to accommodate the links and to resist their reaction.

§ 7.

STEAM-RIVETERS.

In the steam-riveters the force of the crank or elbow-joint is replaced by the pressure of steam on a piston-head. The movable ram is secured on the end of the piston-rod from the steam-cylinder, and thus compresses the rivet.

Fig. 28 illustrates the general form of one type. Of this type there are two varieties. One uses a light ram, and depends solely upon the large piston area for the compression of the rivet. The other variety has considerable

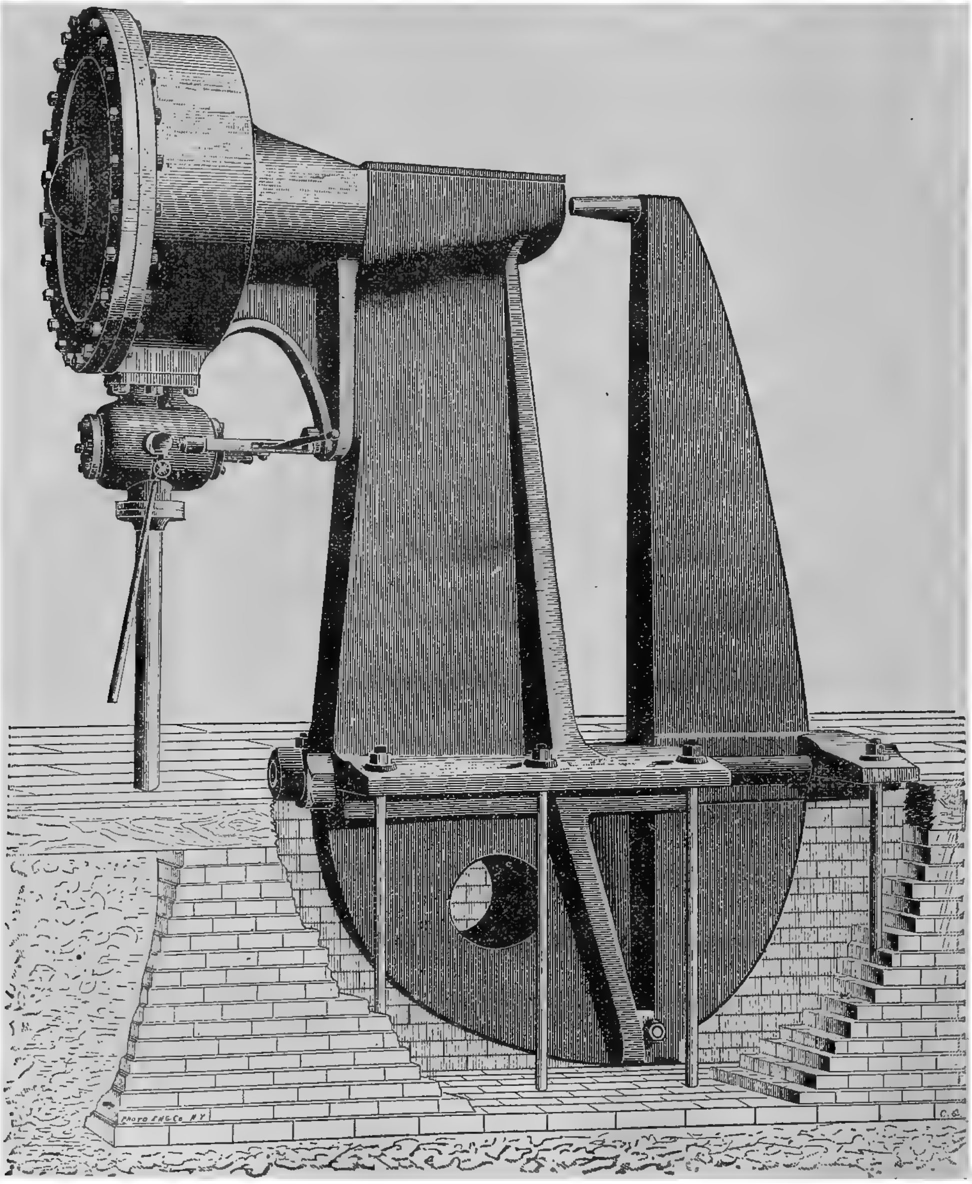


Fig. 28.

weight in the ram and piston, so that when in motion they shall have considerable living force. The compression is effected in part by the living force of this mass and a less diameter of cylinder, and therefore a less volume of steam

suffices for the same work as in the other case. This second variety is the approved form of present practice. The piston and ram are made of one large forging, and steam is admitted through a balanced valve behind the piston. After having delivered the blow some of the steam passes through an equalizing-port into the clearance in front of the piston, and by its expansion, when the exhaust-port is opened, retracts the ram. A second form of steam-riveter in use, but not manufactured at this date, has two cylinders connected to the swaging-ram by bell-crank levers in the horizontal riveters, or by links in the vertical machines. These cylinders are of different diameters, the smaller outer one being connected to the heading-die, while the inner and larger one works an annular ram, which holds the plates together while the heading blow is struck. It is much less simple than the prevailing form.

Steam-riveters, as a class, possess many of the same advantages which steam-hammers have over similar tools driven from shafting. The elasticity of the steam cushions the reaction against the cylinder-head. The position of the machine may be independent of the lines of shafting, since the steam-pipe can be carried anywhere. There is no loss of power nor loss by wear of gear during inactivity

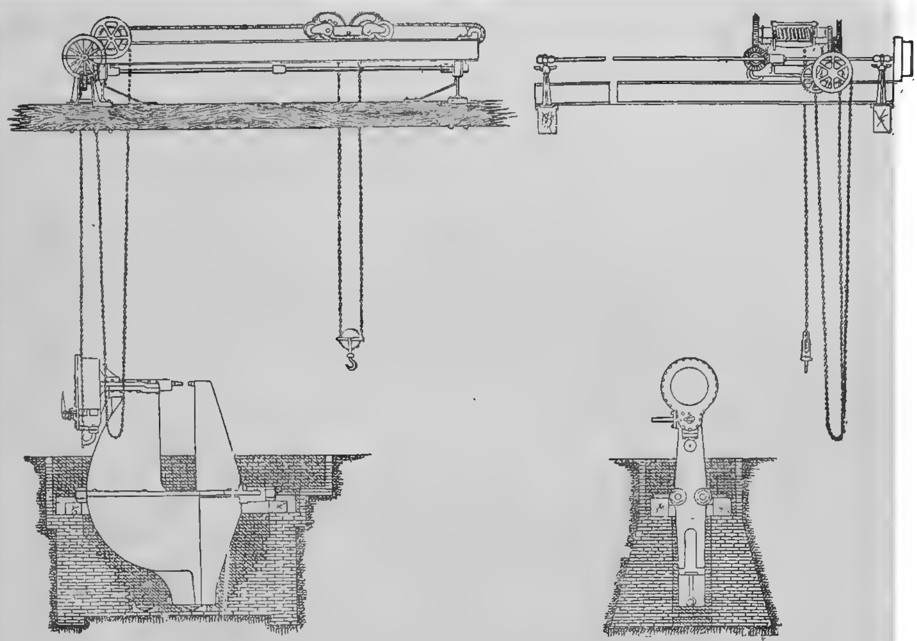


Fig. 29 *a*. Fig. 29 *b*.

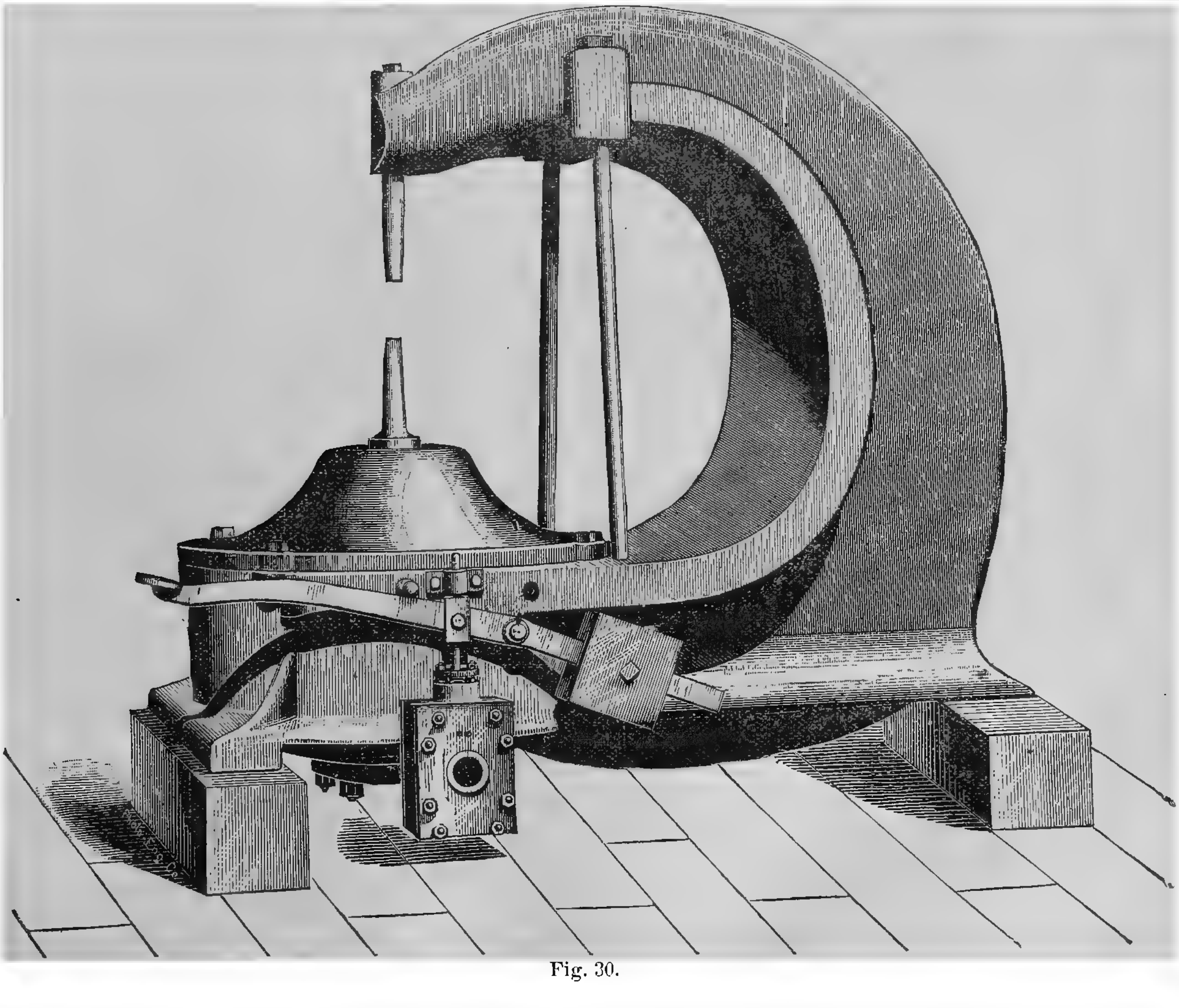


Fig. 30.

of the machine. On the other hand, they deliver a blow upon the rivet before the compression, which causes shocks upon the bolster or stake and wears and strains the machine. There is also a tendency to slide on the foundations, due to the impetus and reaction of the blow, which can only be counteracted by heavy foundations and anchor-bolts. Figs. 29 *a* and 29 *b* show a similar machine with the overhead traveling carriage which accompanies it in the best practice, and Fig. 30 illustrates a horizontally-bedded machine for bridge-work worked by a foot-lever.

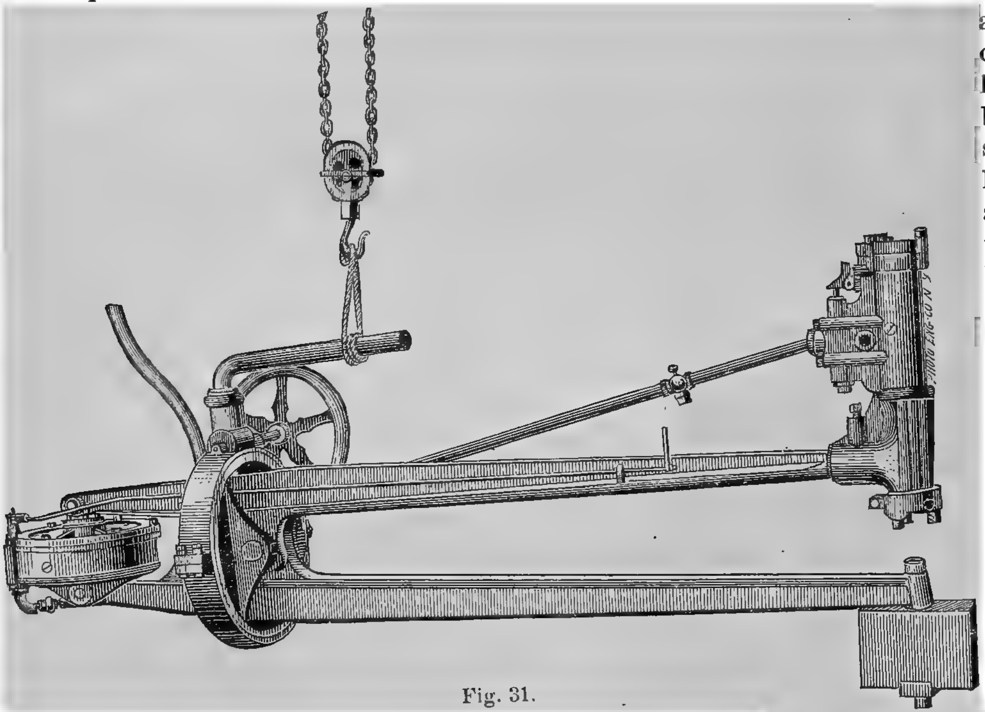


Fig. 31.

§ 8.

AIR-RIVETERS.

The steam-riveter can be worked by compressed air with but little less efficiency. But an especial riveting device to work by air has been introduced which depends upon a different principle. The machine is portable and avoids the expense of foundations. Fig. 31 shows its construction as adapted for boiler-work. The two long arms are pivoted in the suspension ring, which is double, and can be adjusted by the worm and wheel so as to act upon the rivet at any angle. At the farther end is a wide but short cylinder by which the acting ends can be brought together upon the plates before the rivet is inserted. This clamps them together and increases the stiffness of the hold of the stake-arm upon the rivet-head. Upon the free end of the other arm is a small cylinder, with a rivet-swage upon the end of the piston-rod. This small cylinder delivers a number of blows upon the rivet when in place, heading it over upon the clamped plates. About one hundred and fifty or two hundred blows will be delivered per minute, the valve-motion of the cylinder being not unlike that of a rock-drill. The stake-arm has a counterpoise to increase its mass, and the whole machine is swung over its center of gravity. Thirty pounds per square inch is usually sufficient air-pressure.

For work upon girders, where the overreach need not be very large, the form shown in Fig. 32 is used. The machine acts by compression, and not by blows. The air-cylinder opens and closes the links of an elbow-joint upon the outer ends of the nipping-levers.

This form of riveting machinery has the advantages due to its portability, inasmuch as the heavy work does not need to be adjusted to the machine. It also works very rapidly, and steam can replace the air if desired. It is claimed for it that on straight work it will head over two rivets per minute.

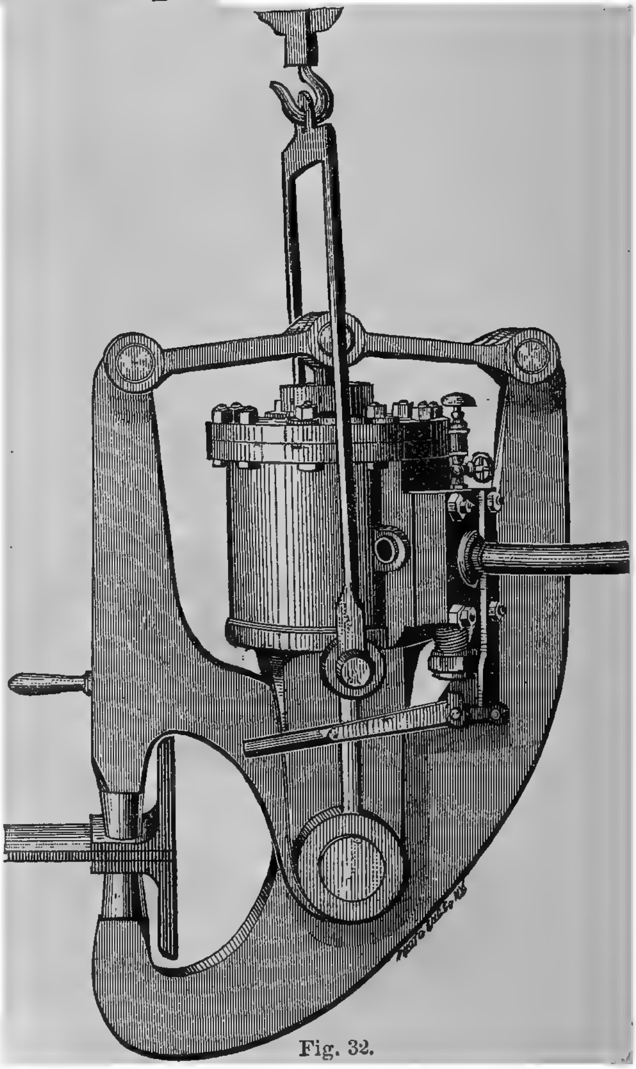


Fig. 32.

§ 9.

WATER OR HYDRAULIC RIVETERS.

The hydraulic riveters differ from the preceding types in the use of an inelastic fluid under great pressures behind the plunger in a smaller cylinder. On account of its density water can be retained at a high pressure per each

square inch, and this pressure upon a small area produces a force equal to that due to lighter steam pressure on a large area. The stationary riveter will, therefore, resemble the steam-riveter, but the cylinder will be much smaller (Figs. 33 and 34). Two essential parts of this hydraulic apparatus must be the pump to produce the water-pressure, and the device known as the "accumulator", to keep the pressure uniform. The pump may be driven by steam directly or by a reducing-gear from a belt-wheel. If the pump were to be the sole dependence to work the riveting-ram it would need to be stopped after each rivet, and would need to have a capacity to fill the barrel of the riveter before the rivet should cool. By the use of the accumulator both these drawbacks are avoided.

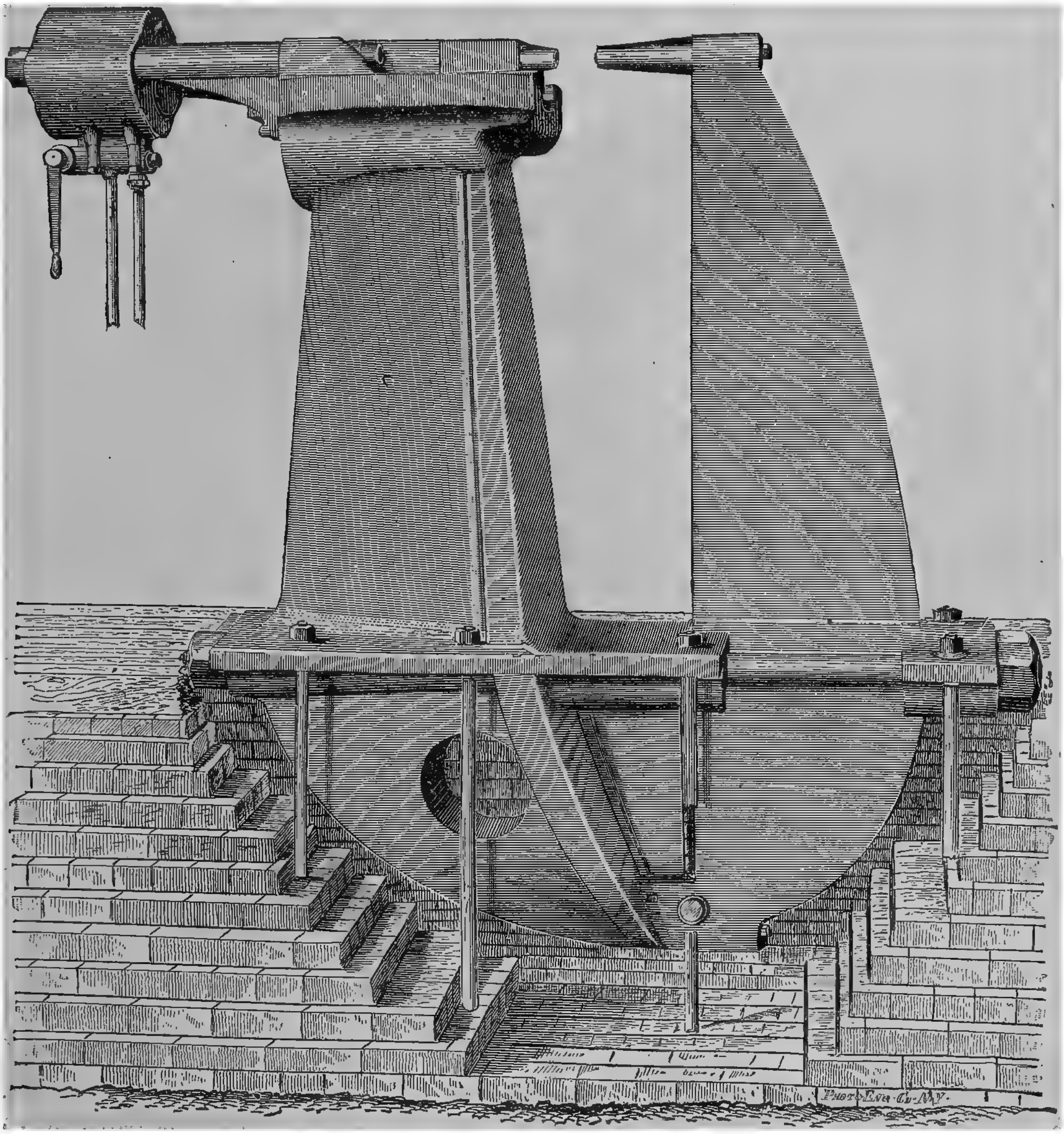


Fig. 33.

The accumulator (Fig. 35) consists of a plunger, which plays through a stuffing-box in the top of a pressure reservoir. Into this reservoir the water is delivered from the pump, and from it is carried to the riveters by pipes, controllable at the machines by valves. It will be seen that when the pumps deliver water into the reservoir, with the outlets closed, the plunger will be floated upward by the accumulating pressure upon its lower end. When an outlet is opened the plunger will sink as the water is withdrawn, but will still maintain the equilibrium between its weight and the pressure of water in the reservoir. By adding weight upon the plunger any desired pressure can be maintained. These weights are hung from the top of the plunger, so that their release or addition can be effected without lifting them into place. When the reservoir is full of water at the desired pressure the accumulator-plunger will be at its highest point. Should the pump continue to force water into the reservoir, the plunger would be forced out. To avoid this, when the plunger has risen to a certain point it opens the valve shown in front by which the forcing-side is connected to the suction-side of the pumps, while the accumulator pressure is shut off. The pump keeps on working under no strain, no more water is added to the accumulator, and yet the pump will resume its normal duty as soon as any water is withdrawn by the machines. Where the pumping is done by a steam-pump, the accumulator-plunger may be connected to a valve in the steam-pipe. When the plunger rises

the steam supply is diminished, as it falls lower the speed of the pump is increased because more steam is given to it. The upright of Fig. 35 is a hollow tank into which the water returns after it is exhausted from the riveters. The water is filtered through sponge on its return to remove any scale, etc., which may have been loosened.

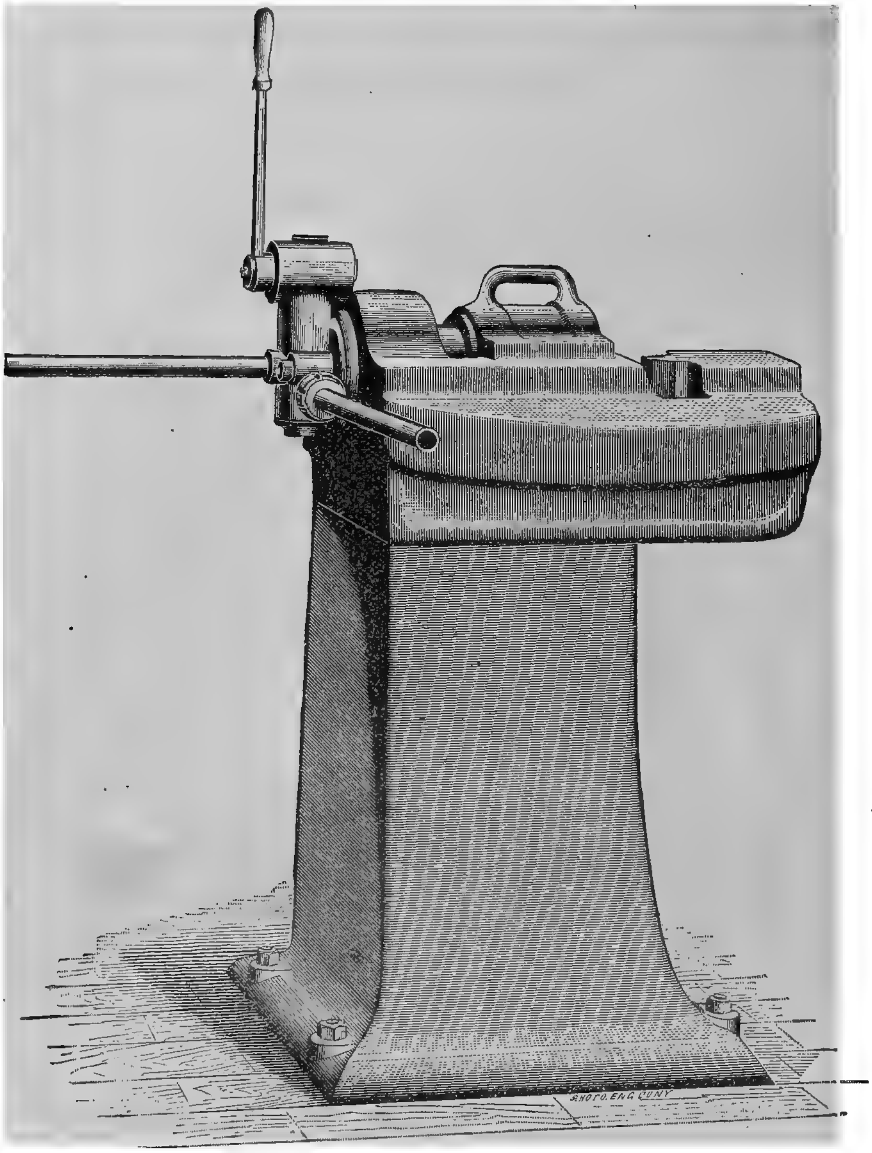


Fig. 34.

For bridge-work, the portable machines shown in Figs. 36 *a*, *b*, and *c* are approved. The machine is hung on the arc from an overhead carriage or from a traveler. It can be presented at any angle to the work, and a worm and wheel gives adjustment in the plane at right angles to the arc. The jaws are levers of the third order, pivoted on a ball-joint at the long ends and held from separating by a spiral spring. Water from the accumulator is admitted to the plunger through a valve and draws the dies together. A reverse motion of the valve-lever shuts off the pressure and opens the exhaust-valve. When the exhaust-valve is open, a small piston attached to the bottom of the barrel serves to draw back the plunger and open the dies. It is claimed for this machine that with it a skillful operator can drive from ten to sixteen rivets per minute in straight work upon girders.

The great advantage of the hydraulic riveter is due to the fact that it compresses the rivets without a blow. The great density of the driving fluid permits its gradual flow through the controlling-valve, and as it has no expansive force of its own, the advance of the ram upon the rivet is a gradual one. The pressure upon the heads of the rivets can never be any greater than that due to the previously determined load on the accumulator. Therefore, the plates can not be forced apart in the joint nor distressed by any excessive pressure in the upsetting. They have hitherto been open to the drawbacks due to the high pressures at which they were worked. An average pressure was from 1,000 to 1,800 pounds per square inch, but this pressure is very severe upon the packing of the rams. Leather cup-packing seems to give the best results, but it is cut sharply through at the bends. Practice is therefore tending to reduce the pressures and enlarge the plunger areas. Pressures of 350 pounds to the square inch are much less difficult to manage, and the advantages of riveting by an inelastic pressure are retained. For girder-work in yards, or under open sheds in winter, there may be dangers from freezing of the water, against which special precautions must be taken.

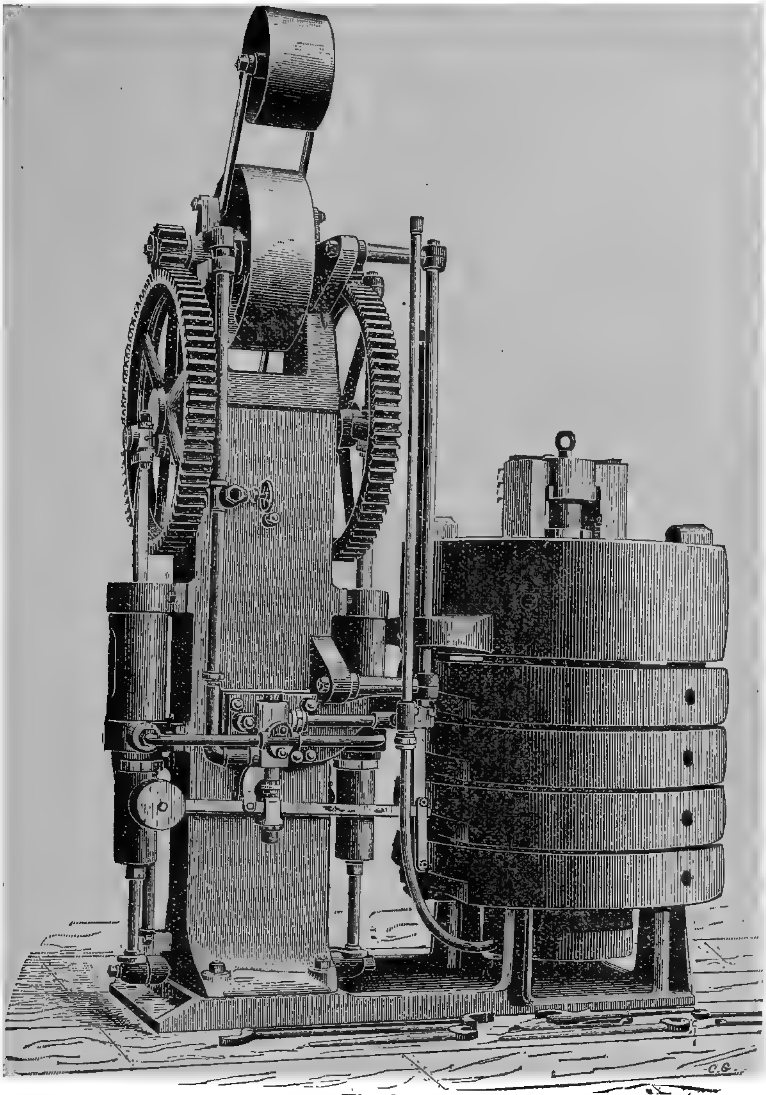


Fig. 35.

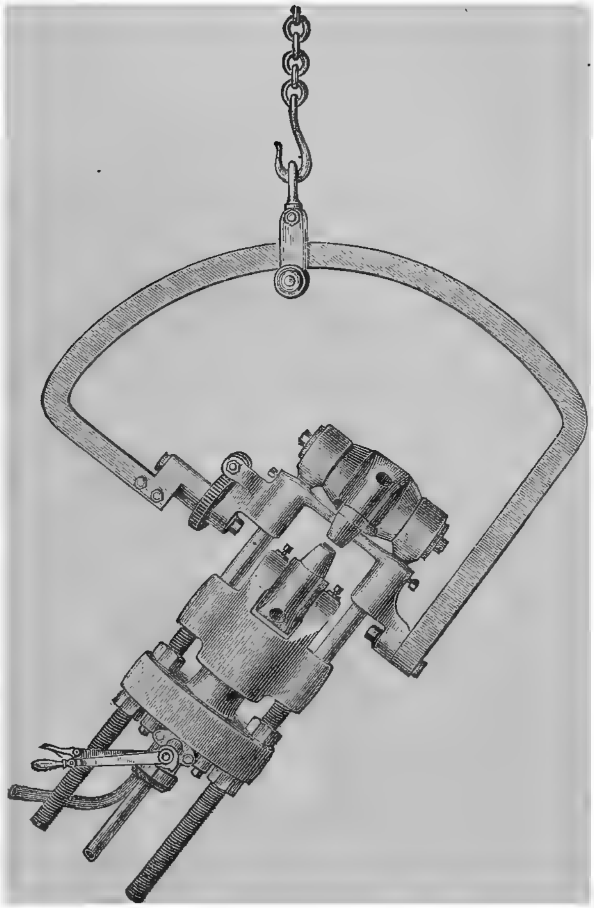


Fig. 36 *b*.

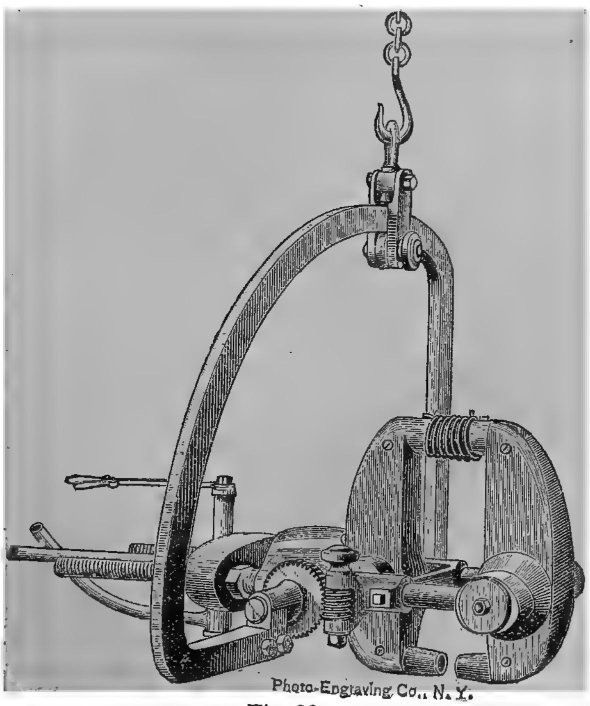


Fig. 36 *a*.

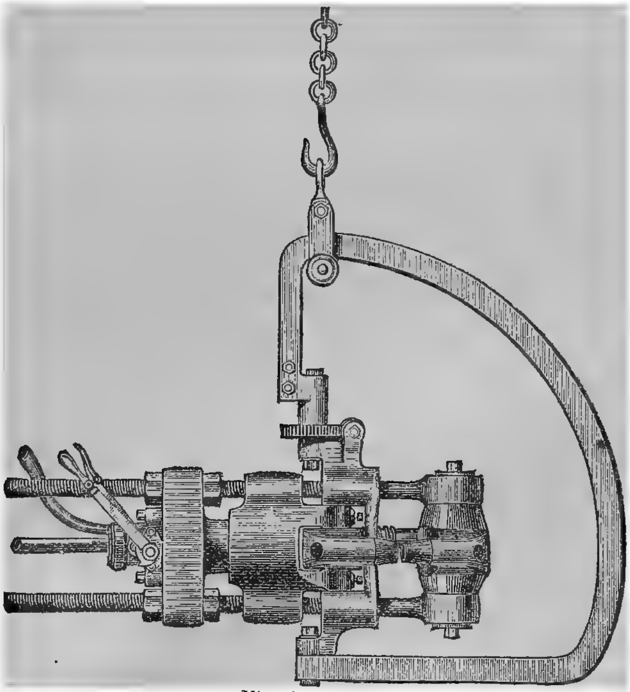


Fig. 36 *c*.

§ 10.

DIE-FORGING MACHINERY.

The principle of these machines is but an extension of that on which hydraulic riveting is based. The material to be shaped is exposed at a welding heat to great pressures between dies which are actuated by hydraulic plungers. Every part of the die is completely filled by this pressure, and an exact reproduction is obtained. The effect of this gradual pressure upon the forging is much more favorable than the effect of hammer blows. Blows upon the

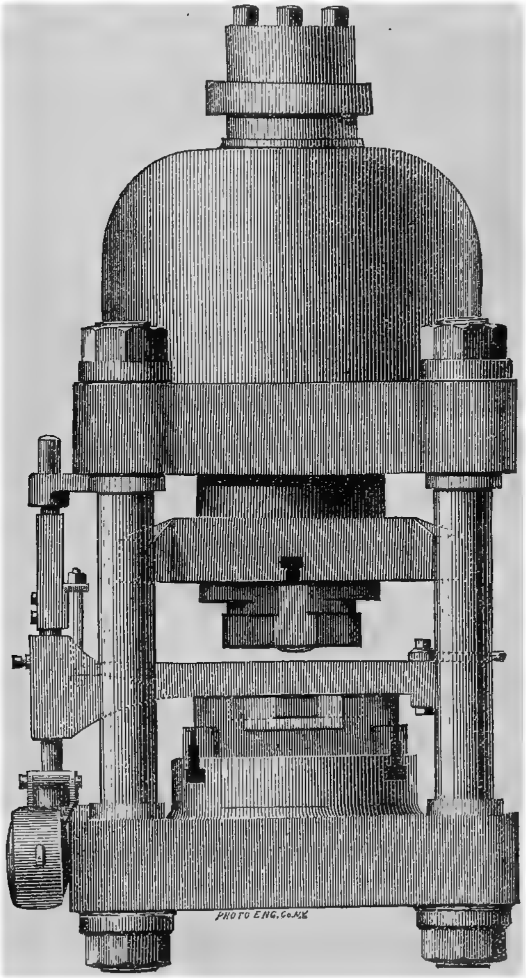


Fig 37.

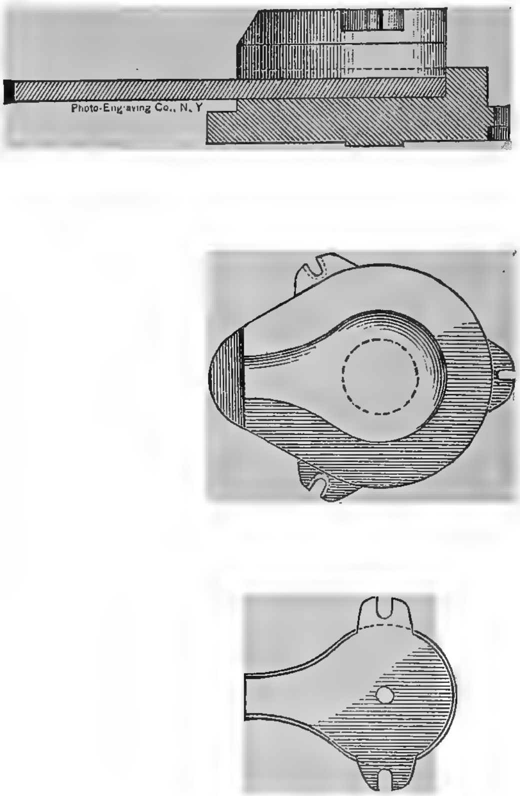


Fig 38.

forging delivered through a fuller or swage often act upon the surface only, and leave the interior parts less affected. This is shown by the drawing out of the top and the bottom of a forging farther than the center. In rolling this phenomenon gives rise to "pipes". The gradual pressure forces out the material in the middle first, thus showing the compression to have been pervasive.

This process of die-forging has been applied with especial success to the manufacture of eye-bars or chord-links for bridges. The enlarged head or eye is formed from the metal of the bar without the weakening effect of a common weld, and with much greater economy.

Two sets of presses are employed. The first upsets the end of the bar into approximately the finished profile, while the neck of the bar below the heat is closely gripped between serrated jaws. The heat is restored to the end to relieve the strain at the neck, and it is put in a flatting-press with male and female die and brought to the exact shape and thickness (Fig. 37). A nipple on the male die makes a central depression upon the eye where the pin-hole comes (Fig. 38), which depression guides the punch which forms the hole. The punch is usually hydraulic—shaped and acting like a vertical riveter. The only loss of metal is by scale and the small fin at the dies. The punched blanks can be welded under pressure and utilized as nuts. One difficulty met with is the danger of thinning the bar at the joint of eye and straight length.

Two accumulators are used to furnish the hydraulic pressure for the presses. One is weighted to produce 400 pounds or so to the square inch of plunger, and water is taken from this to fill the plunger-barrel and to exert

what pressure it will. Then, if necessary, the first valve is closed and communication is made with the second accumulator, which is weighted to 2,500 pounds to the square inch. Less water at the heavier pressure is thereby

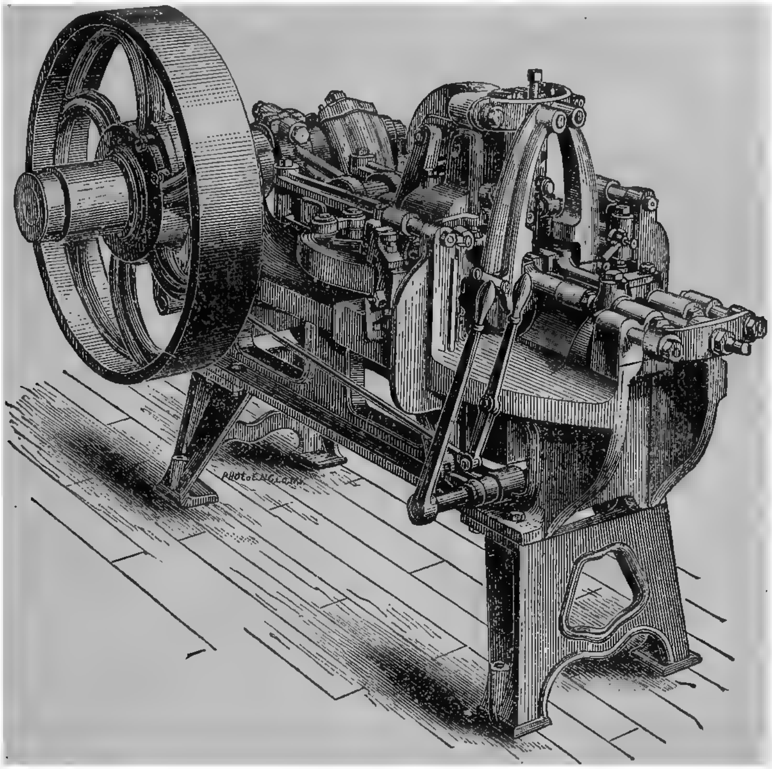


Fig. 39.

used, resulting in a saving of the power necessary, but many works are using only one accumulator to avoid the greater first cost.

This principle of forging between dies by hydraulic pressure can be carried very much further and applied to many shapes. The saving of time and the superiority of product are to be set over against the first cost of the plant.

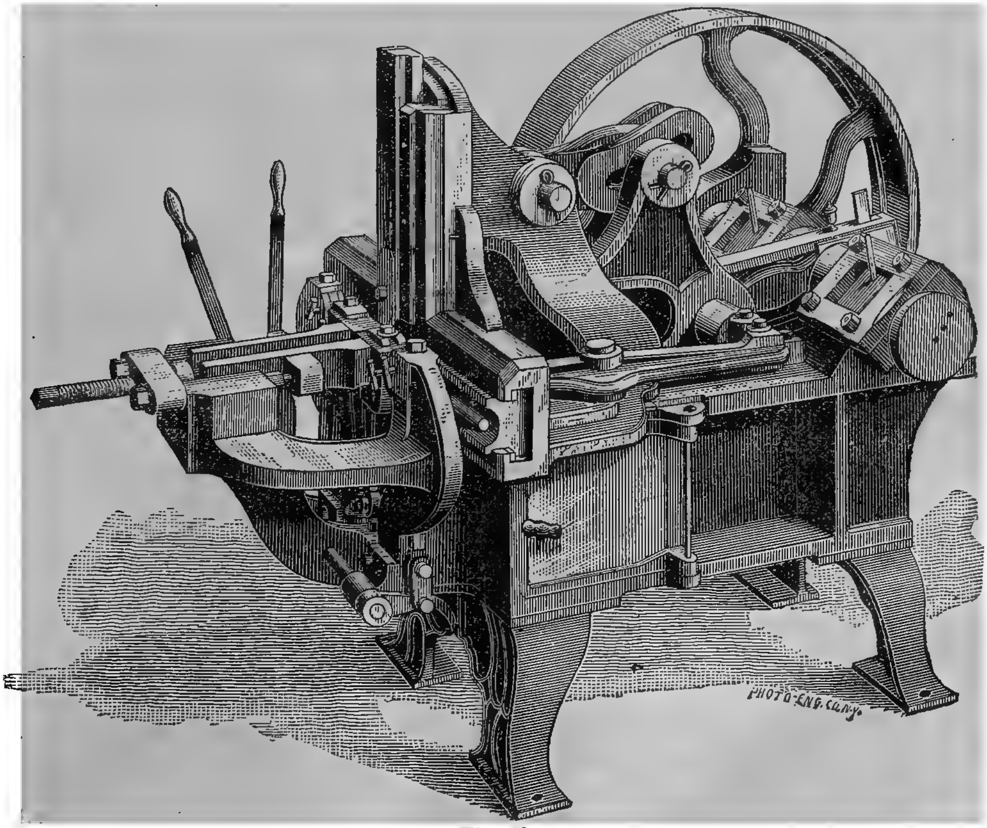


Fig. 40.

Another method upsets the end of the bar by pressure of a ram driven by steam pressure. The bar is held between plungers, from which hydraulic pressure is relieved through a small valve as the upset is made. This yielding grip is thought to distress the bar less than a rigid clamp. Upon the upset end a piece is welded to make up the thickness when the eye is formed between dies on head and anvil of a steam-hammer.

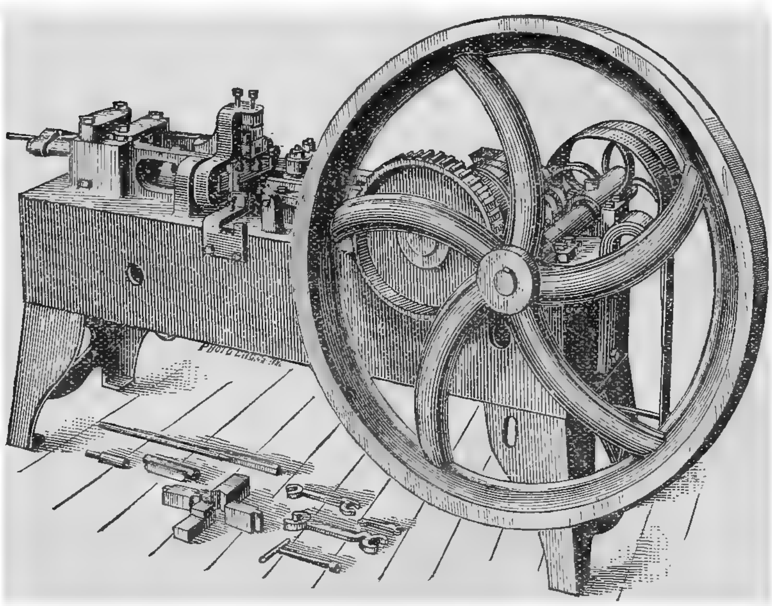


Fig. 41.

Under die-forging machinery must also be included the machines for making bolts and nuts. Many large shops which use a great number of bolts of different forms prefer to head over their own stock in the blacksmith shop, and for such work these tools are adapted. Fig. 39 shows the Burdict improved bolt-forger; Fig. 40 is the Abbe machine, an outgrowth of the former, and Fig. 41 shows the Burdict machine for making hot-pressed nuts from the bar.

In the bolt-header (Fig. 39) the iron is held between clamp-dies which are moved by the hand-lever at the extreme right. The grip is by means of an elbow-joint, and is for steadiness only. The blank is kept from end motion by a screw-stop at the end of the vise. Hence there will be no change of section of the rod under the heated head. Blows are delivered upon the end of the blank by the upset-die, which is connected to a short crank on the fly-wheel shaft, and the forming-dies in pairs act laterally upon the upset metal. The formers act twice for every one blow of the upset. The forging-levers act only when engaged by a clutch operated by the second hand-lever, thus avoiding unnecessary wear. The slides of the formers are gibbed to take up wear, and the pin-joints are bushed. The links from the long slide of the upset make an elbow-joint combination with the side levers, and the top and bottom swages are moved by a pin working in a curved slot. Four revolutions of the shaft will form a head, and from 3,000 to 8,000 bolts is the capacity of the machine in ten hours.

Fig. 42 illustrates another type. The nut-machine (Fig. 41) makes the nut at one operation without fin or burr, saving the expense of trimming the blanks.

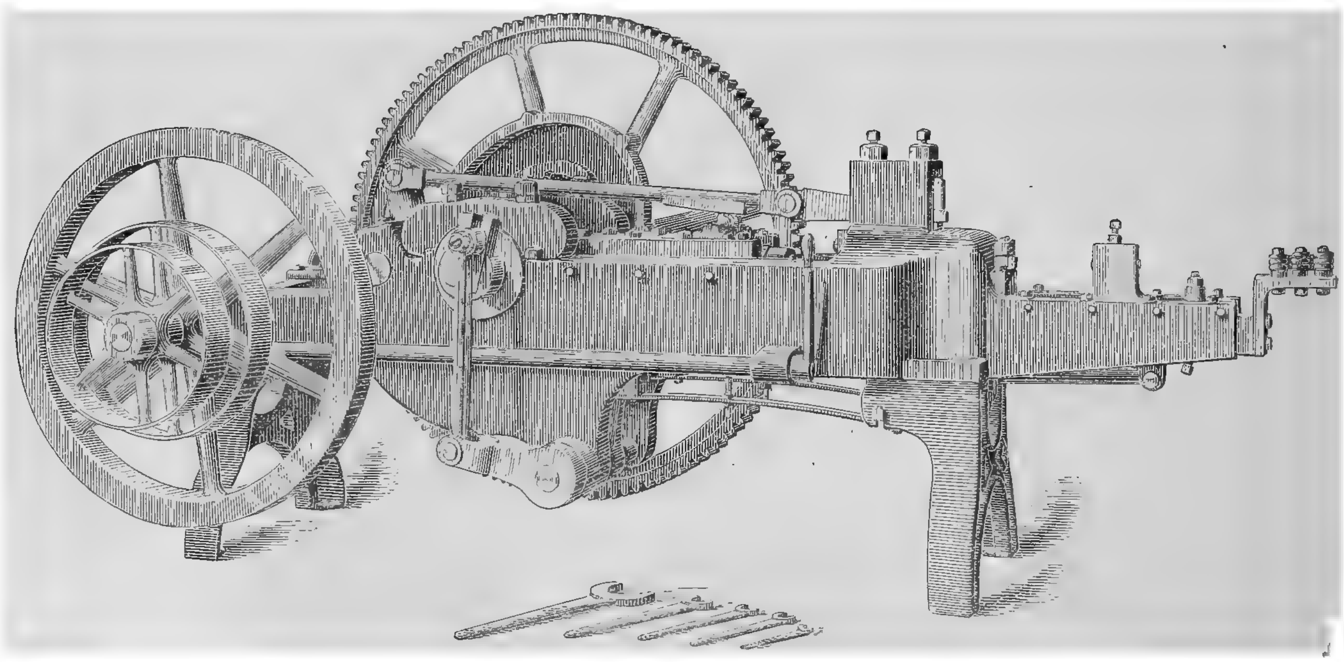


Fig. 42.

There is a variety of other machines which might come under this class, such as the rivet, spike, nail, and horse-shoe machinery, but as these are machines manufacturing directly and only for the market, in accordance with the original plan they will be passed over.

§11.

BENDING-ROLLS—STRAIGHTENING- AND BENDING-PRESSES—ASSEMBLING-PRESSES.

BENDING-ROLLS.

For curving plate iron or steel for boiler purposes, or for other cases where cold shaping may be required, the combination of three rolls is used. This appears in two forms. The two lower driven rolls may be fixed, and lie in the same horizontal plane, while the third roll lies above the other two and over the hollow between them. This top roll is adjustable vertically to give the required degree of curvature. The other form has the upper and one lower roll fixed and driven, while the third roll is adjustable obliquely toward the other two (Fig. 43). The adjustable roll is not driven in either case. The first form has the advantage of causing no calendering action. The curving takes place round the adjustable roll, which is not driven, and the two driven rolls both act upon the outside surface. The disadvantage is that it is not

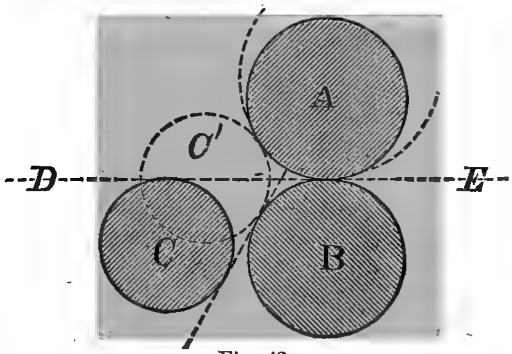


Fig. 43.

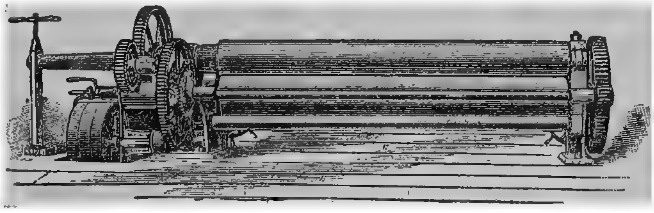


Fig. 44.

easy to start the plate into the rolls, and that they will not curve it exactly near the edges of the plate. In the second form the two driven rolls pinch the plate, so that it must enter, and the third roll bends close to the edge.

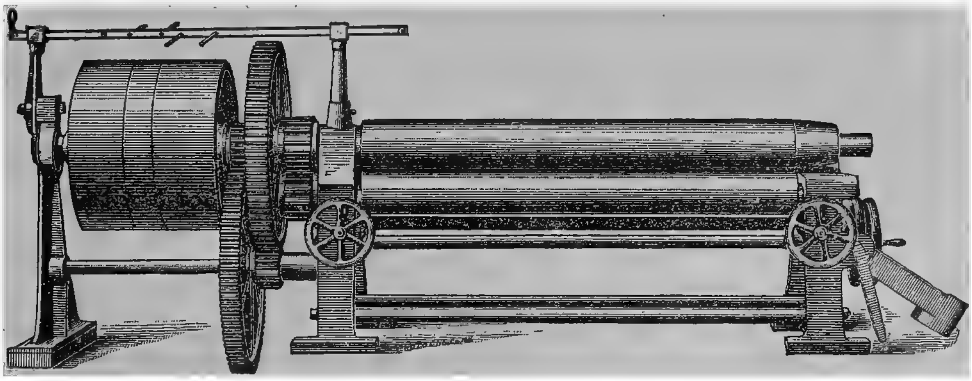


Fig. 45.

But the upper roll is acting upon a surface of less length than the lower after the piece is curved, yet they are driven at the same speed. To obviate the frictional loss from this inequality the lower roll, in the best practice,

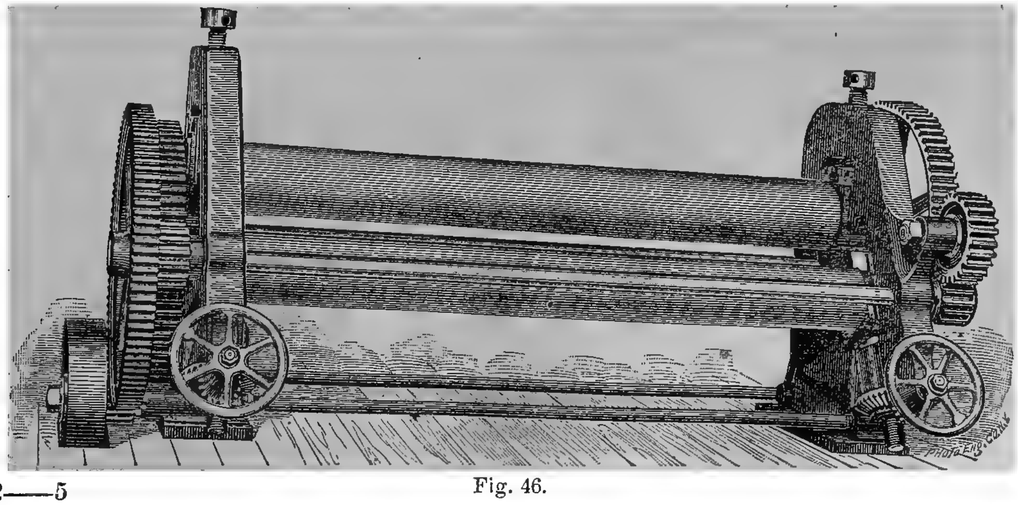


Fig. 46.

is driven by an epicyclic gear, so that the excess of length may be compensated for and pass into the gear (Fig. 44). This avoids also the calendering of the plate. The compensating gear consists in a set of four bevel-wheels forming a rectangle, the two smaller ones being upon a diameter of the wheel which drives both rolls, and of the other two, one is connected to the gear on the upper roll and the other to the gear of the lower. Any inequality of resistance in the rolls is equalized by the rolling of the small bevel-wheels upon the larger. The rolls are geared at both ends by large gears and small pinions, so that they shall drive truly. They are driven by open and crossed belt, with one fast and two loose pulleys. The shifters may either be plain forks, or else some of the special designs may be used, by which one belt is shifted off before the other is shifted on. The housing of the upper roll is made removable, in order that flues or any other work rolled into a full cylinder can be taken off. In the form shown in Fig. 45 the roll need not be lifted that the flue may clear. The design of Fig. 44 makes the lifting necessary. The screws for lifting the two ends of the curving-roll are usually geared together, that true cylindrical curvature may be given. When the plates are to be bent into-wind, as in ship-work, they may either be presented diagonally or the two ends of the curving roll may be raised unequally (Fig. 47). In the pyramidal form the rolls must be brought together with the work between them. Not infrequently, therefore, the adjusting-screws are headed by worm-wheels and driven by power. With the other form hand-gear only is necessary, and is preferable from its greater exactness (Fig. 46).

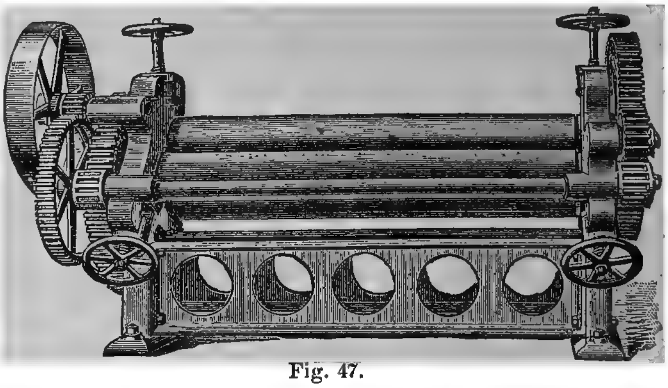


Fig. 47.

Where the rolls are revolved by hand-spikes, and one lower and the upper roll may be driven, the pyramidal form is approved, because of its simplicity. For power-driven rolls, the other arrangement is preferred.

§ 12.

STRAIGHTENING- AND BENDING-PRESSES.

After work has left a roll-train and has become cool, it is very often found to be out of true. Unequal contraction, if the work was finished hot, may produce this result, the shape may have compelled calendering, or the removal of a skin which kept the work straight in the rough may also cause it. In either case straightening machinery is made necessary.

To straighten a curved beam or rail a heavy pressure is to be exerted upon the work through a short distance, while it is held upon two supports. The machine may be either horizontal or vertical, and usually acts upon the principle of the crank, the crank and connecting-rod forming an elbow-joint combination. The essential parts will therefore be the two abutments for the support of the work, and a crank-shaft which can be adjusted with respect to the abutments for different thicknesses of work and different amounts of curvature.

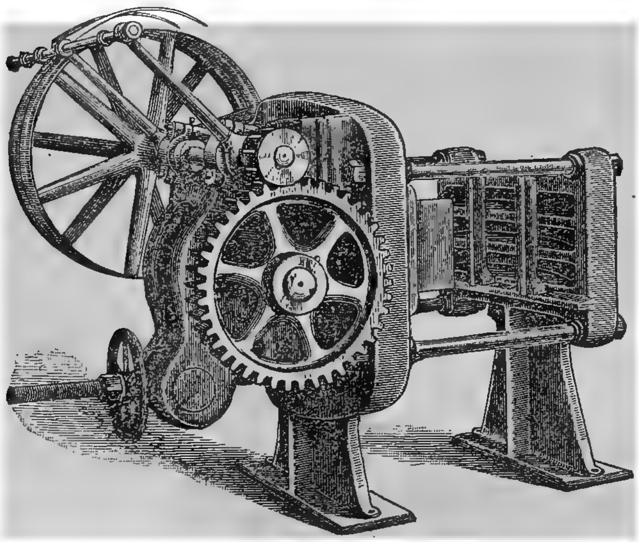


Fig. 48.

Fig. 48 shows a horizontal machine of this class. The abutments are tied to the plunger frame by the four bolts, and the bearings of the crank-shaft are borne upon the heavy frame swinging around the center of the pinion-shaft. By tightening the hand-wheel nut the end of the bending-plunger comes nearer to the abutment. The gear-wheel travels around the pinion, always remaining in gear with it. A vertical machine for similar purposes is also made, whose mechanism resembles closely that of the vertical punches. The horizontal machine is especially adapted for working upon bridge or other girder work, as the parts lie horizontally upon trestles, at an easy height for sighting. By raising the height of the abutment supports of these machines, they can be used for curving straight work for any uses for which such pieces may be required.

Fig. 49 illustrates a hydraulic machine for curving railroad-iron. The abutment may be changed for different degrees of curvature, and the bending speed may be varied by the lever without stopping the pump.

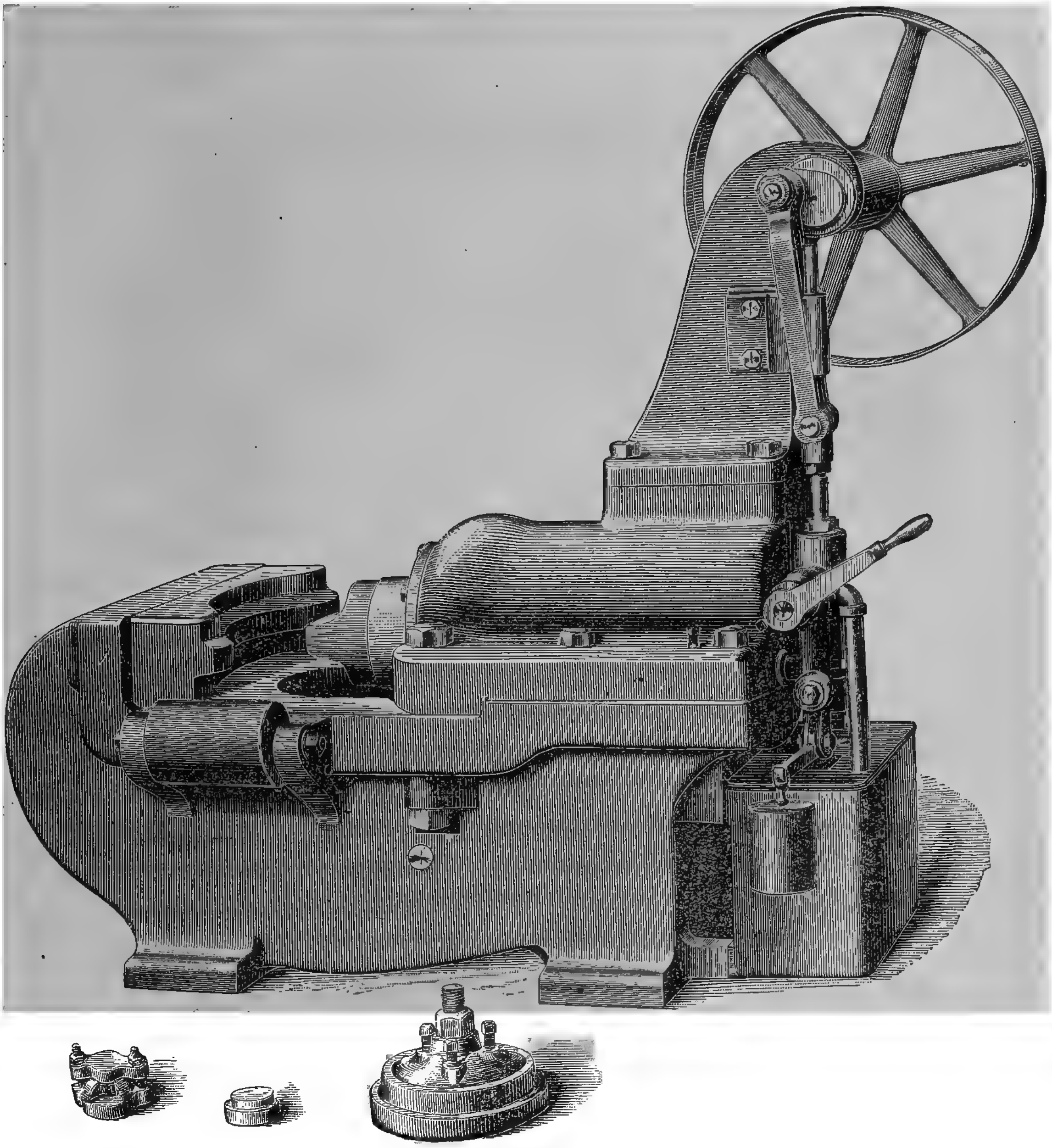


Fig. 49.

§ 13.

ASSEMBLING-PRESSES.

Under this head come those machines which are used in putting together the parts of engineering work. They are most generally applied for putting crank-pins into cranks, and for forcing the wheels of cars and locomotives upon their axles. The principle of the hydraulic press is most generally applied, inasmuch as that has the advantages of slow velocities and very great power, and the exact pressure can be known by a pressure-gauge. The machine must consist of an abutment to resist the pressure of the ram, the supports for the work, the cylinder and frame for the ram, and the pump and its gear.

Figs. 50, 51, 52, and 53 show the general forms. The pumps are usually double, to insure regular motion of the ram. Designs (Figs. 52 and 53) have the pumps of different diameters. When the larger one is working the ram moves rapidly. When the limit of its capacity is reached it can be shut off by a hand-wheel, and the smaller pump will complete the pressure to the limit of the machine. At 100 strokes per minute no irregularity of motion is felt. The fluid used is oil taken from a reservoir in the base of the frame. When the work has been forced home, the pressure can be let off into the reservoir by turning the large hand-wheel and the ram is retracted

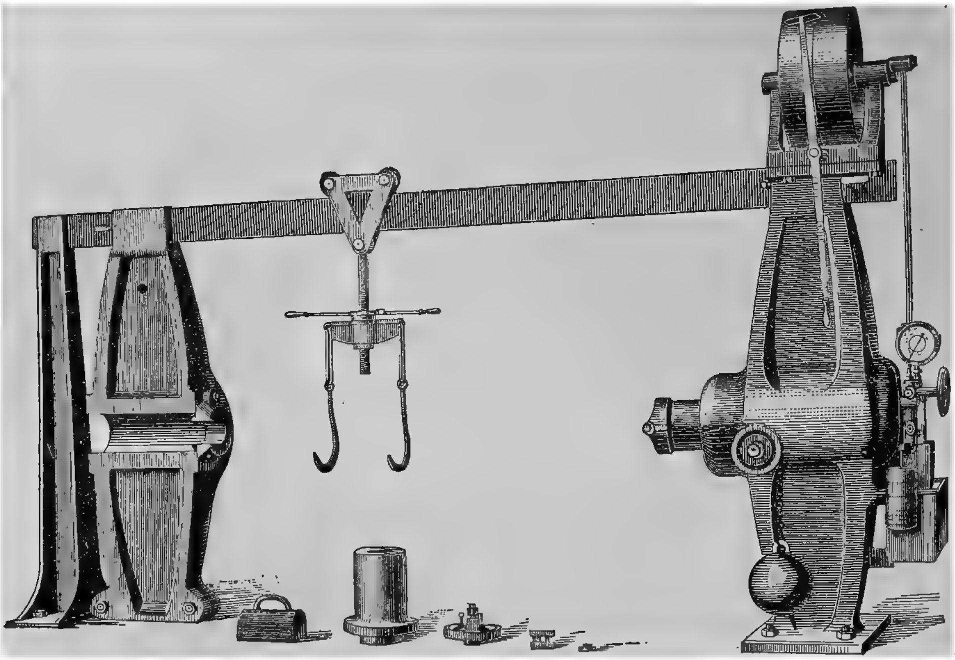


Fig. 50.

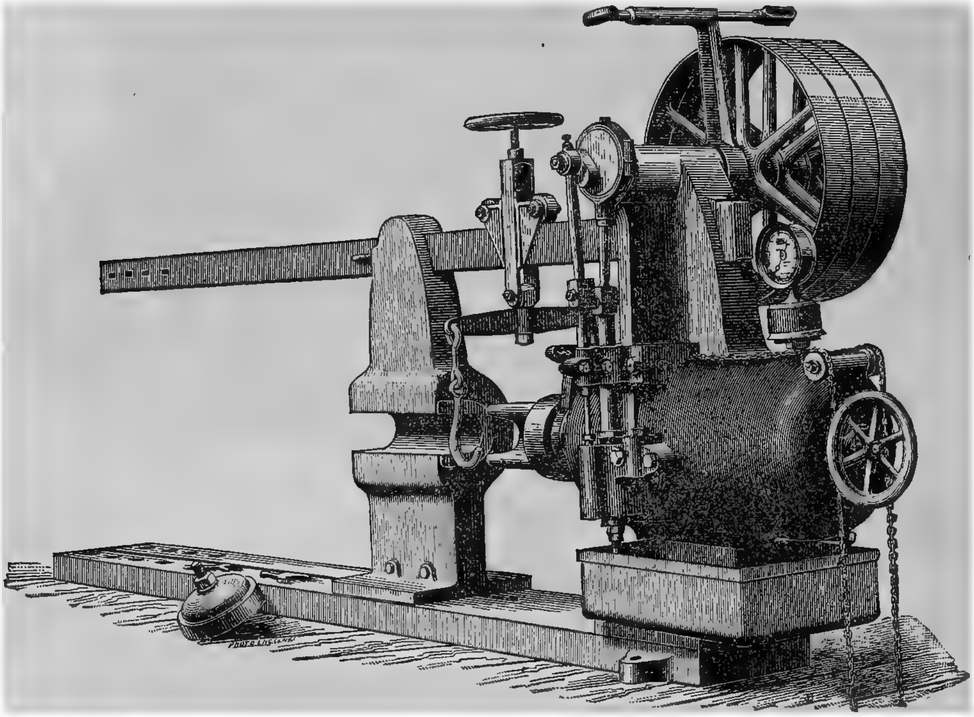


Fig. 51.

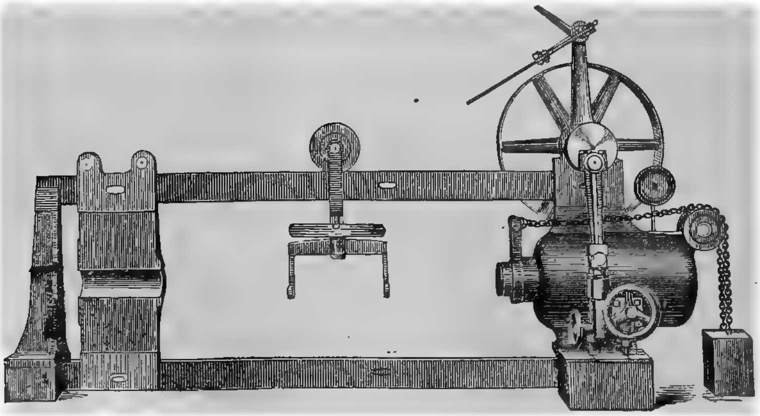


Fig. 52.

by the counterpoise. The ram-cylinder is provided with a safety-valve (often put beyond the control of the operator) and a pressure-gauge. To prevent the sweating which cast iron will manifest under high pressures, one builder lines the cylinder with seamless copper expanded against the lining. Cup-leather packing is used for the gland, made upon formers which accompany the machine.

The abutment is tied to the ram-cylinder casting by the sole-plate below and the reach-rod above. The abutment is fitted with rollers either above or below to make easy the adjustments for different lengths, and is held in place by keys at top and bottom. It can thus be used to take apart work as well as to force it on. From a buggy on the reach hangs an equalizing beam, adjustable for different diameters by the screw- and hand-wheel. It will support any work in the line of the axis of the machine and over its center of gravity.

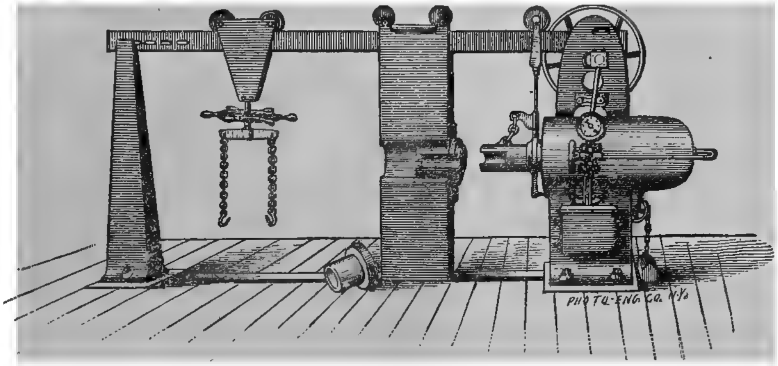


Fig. 53.

These assembling-presses have become almost a necessity. In car-axle work, where the "wheel-fit" on the axle is made cylindrical and seven-thousandths of an inch larger than the hole in the wheel, practice has shown that the wheels will never come off when forced in place by a pressure of 30 tons. To get this by the old hand-screw press would be very laborious and would take entirely too much time, while it would be hard to ascertain exactly what pressure was being applied. The hydraulic press avoids all these difficulties, and is therefore in very general use.

§ 14.

B.—TOOLS ACTING BY SHEARING.

This class includes those tools which act upon the metal by cutting through or cutting off the fibers or elongated crystals of which it is composed. This may be done by perforating the metal as when a plate is punched, or by separating it into two parts at a vertical plane as when a bar is sheared.

The tools in this class will therefore be the punches and the shears. They can be discussed together, since their action and construction are identical. There must always be found the abutment upon which the metal must rest, and an edge or plane through which the shearing force will pass. In the shearing-machines these two are straight; in the punches they are circular.

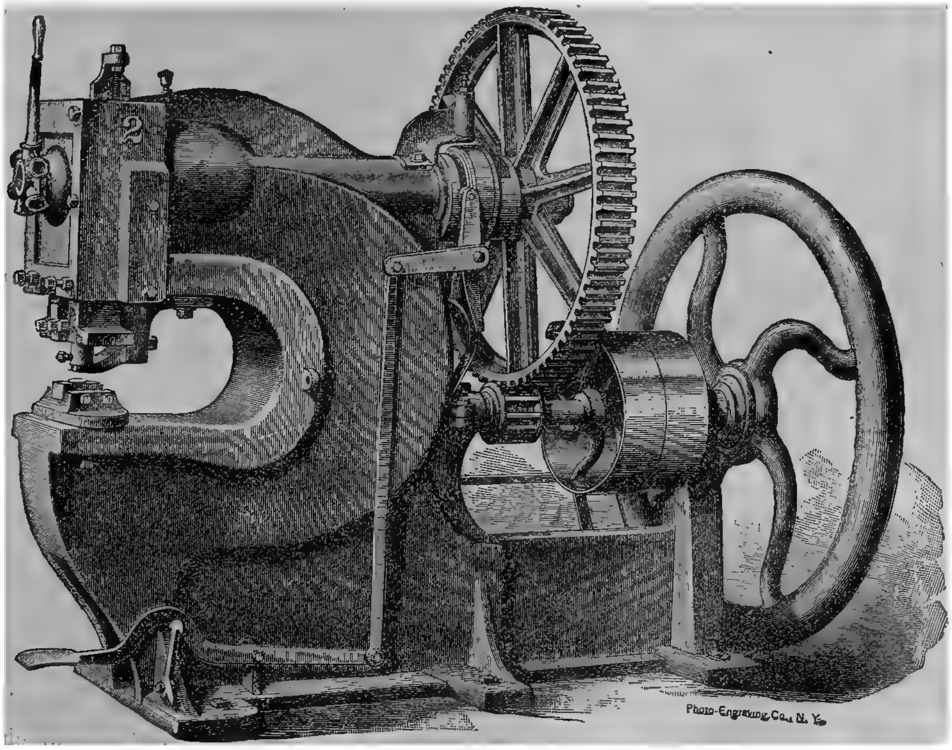


Fig. 54.

Shearing-machines may be reciprocating or rotary. Punches can be reciprocating only, from their nature. They are usually driven by belting from the line shafting of the shop. Increasingly, however, practice is tending toward the use of a separate engine for each large tool of this class. The cylinder is bolted to the framing, and it

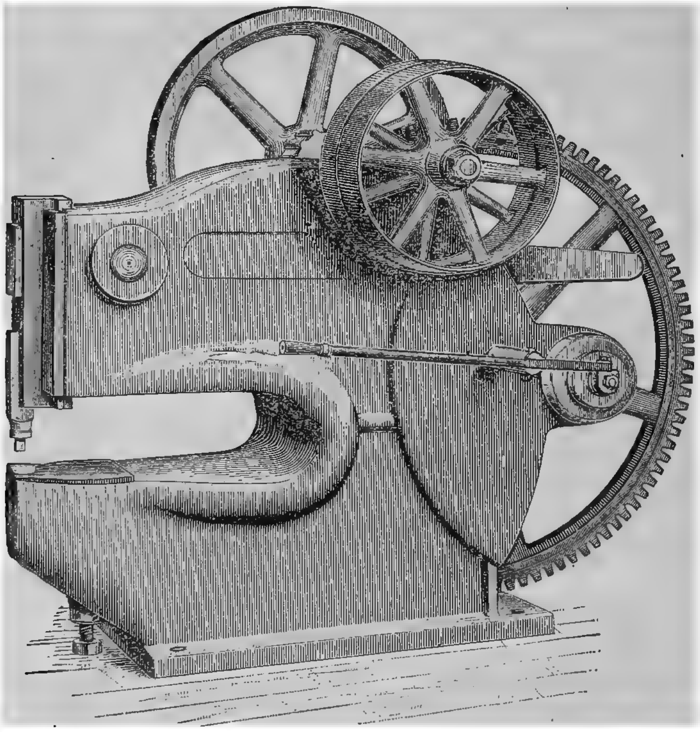


Fig. 55.

uses the former belt-shaft for its fly-wheel shaft. This system has the advantage of rendering the tool independent Any stoppage of the machinery does not arrest its work, and it can be put wherever most convenient, without regard to the conditions imposed by shafting, etc.

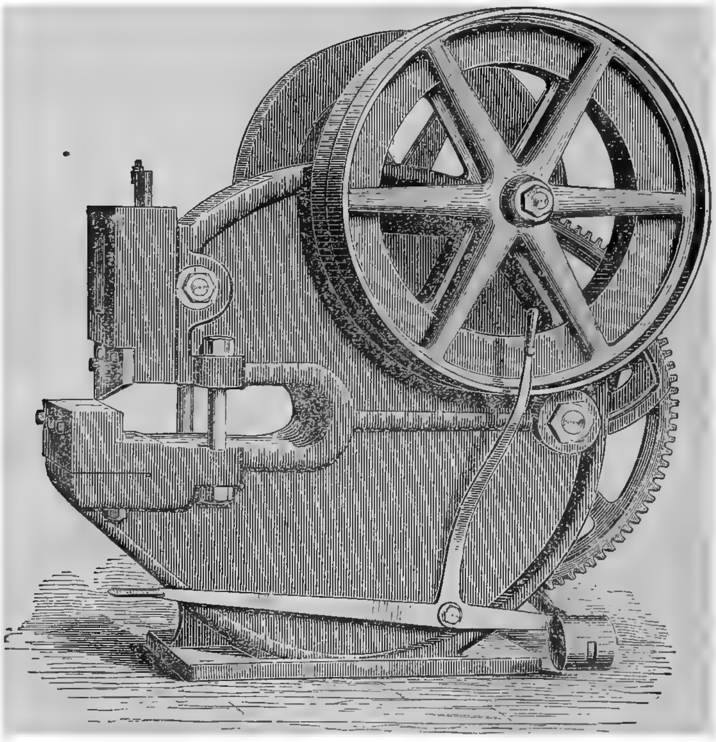


Fig. 56.

The reciprocating machines, punches, and shears can be grouped under two classes. The first includes those in which the slide carrying the shearing-plane is moved by a crank or eccentric. The second class includes those in which motion is given through a lever to the shearing-plane.

The disadvantages of the crank-system are that the strain of the cut must be borne upon the crank-pin, which must necessarily overhang, and the power of such machines is limited to the pressure practicable upon rubbing surfaces of the area of the pins. These rubbing surfaces being therefore, of necessity, large, the work of friction

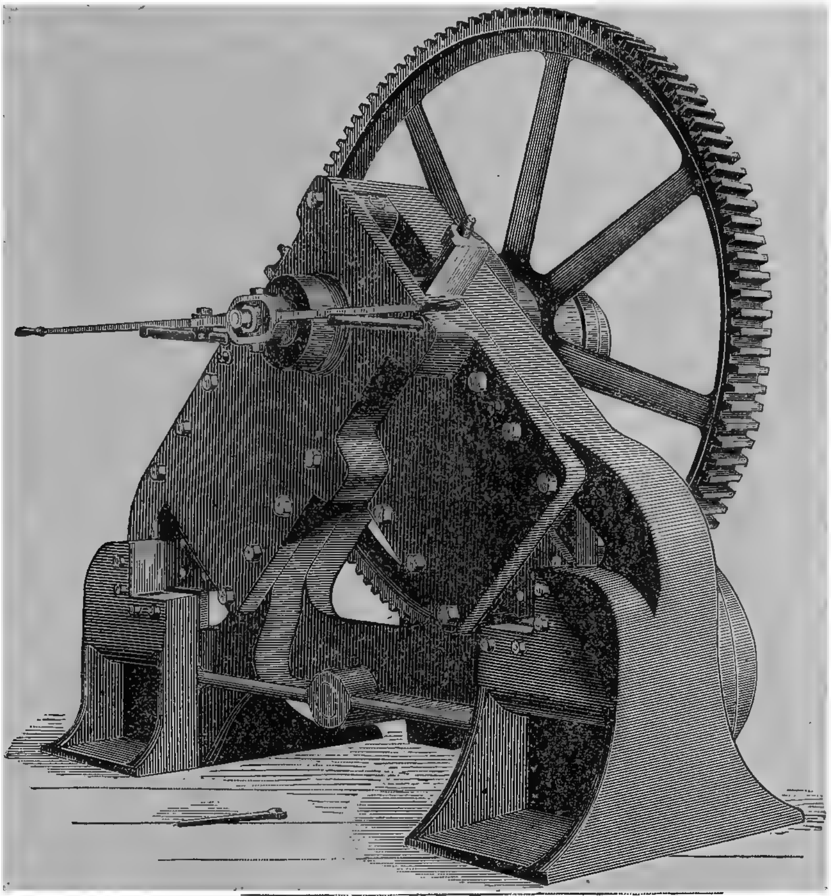


Fig. 57.

upon the circumference of the pin is also large, absorbing some of the power of the machine. The crank-system has the advantages of compactness, of distributed pressure upon the crank-shaft bearings, and of ready adjustability

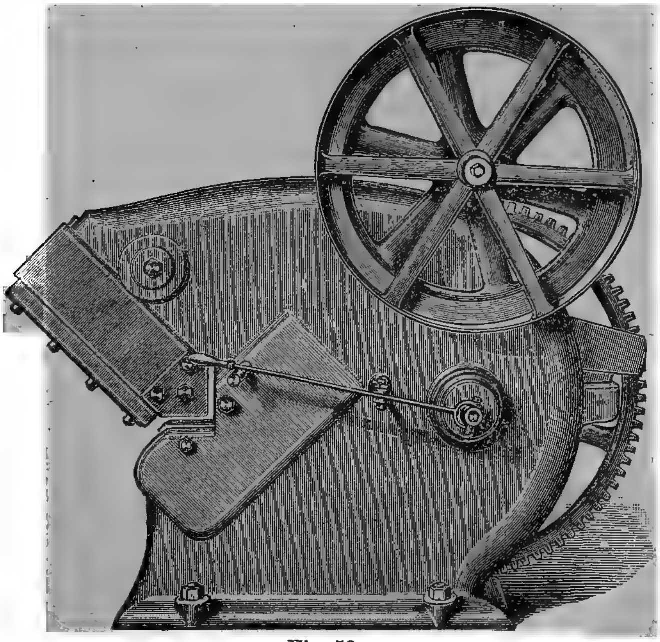


Fig. 58.

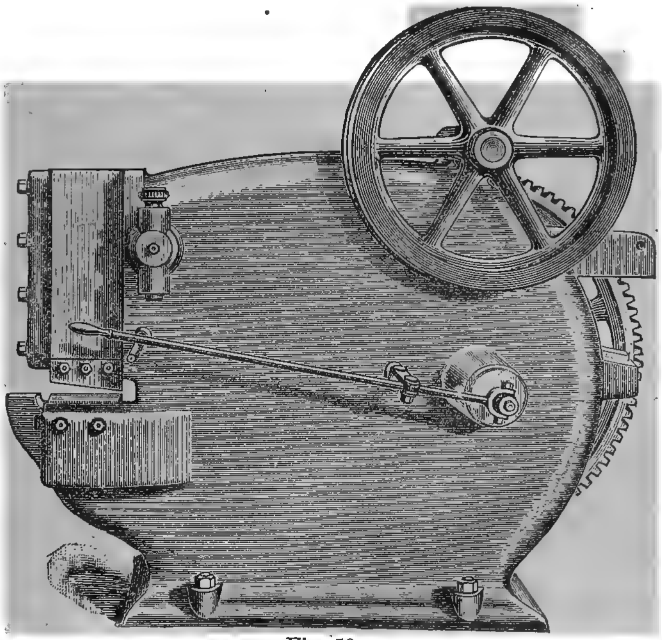


Fig. 59.

from in front. The power of the crank as it straightens into the line of the cut is very great. The disadvantages of the lever-system are that the necessity for metal at the fulcrum diminishes the capacity of the machine, and the

cam should have a double bearing to prevent the slide from being caught down, since, when released, the lever will fall with a heavy blow. Moreover, the stroke and release are of the nature of a shock, which causes the metal of the lever and of the frame to become fatigued.

The advantages of the lever-system are the diminished sliding of the rubbing surfaces at slide and at fulcrum, where pressure is great, while the cam at the long end of the lever works under lighter pressures, so that the work of friction is lessened. Moreover, the cam may be shaped to give a quick-return motion, and to permit the shearing-plane to remain stationary at the top of its stroke during a large part of a revolution. This makes the handling of work more easy, and may prevent the necessity of stopping the machine after a stroke.

In view of the close equivalence of the reasons in favor of the two systems, the prevailing practice favors both about equally. Most engineers prefer what they have been accustomed to.

Fig. 54 shows a very good illustration of the crank-punch or shear. A fast-and-loose belt-wheel shaft, carrying a fly-wheel, drives a pinion which turns a large gear loose on the crank-shaft. This gear can be clutched to the

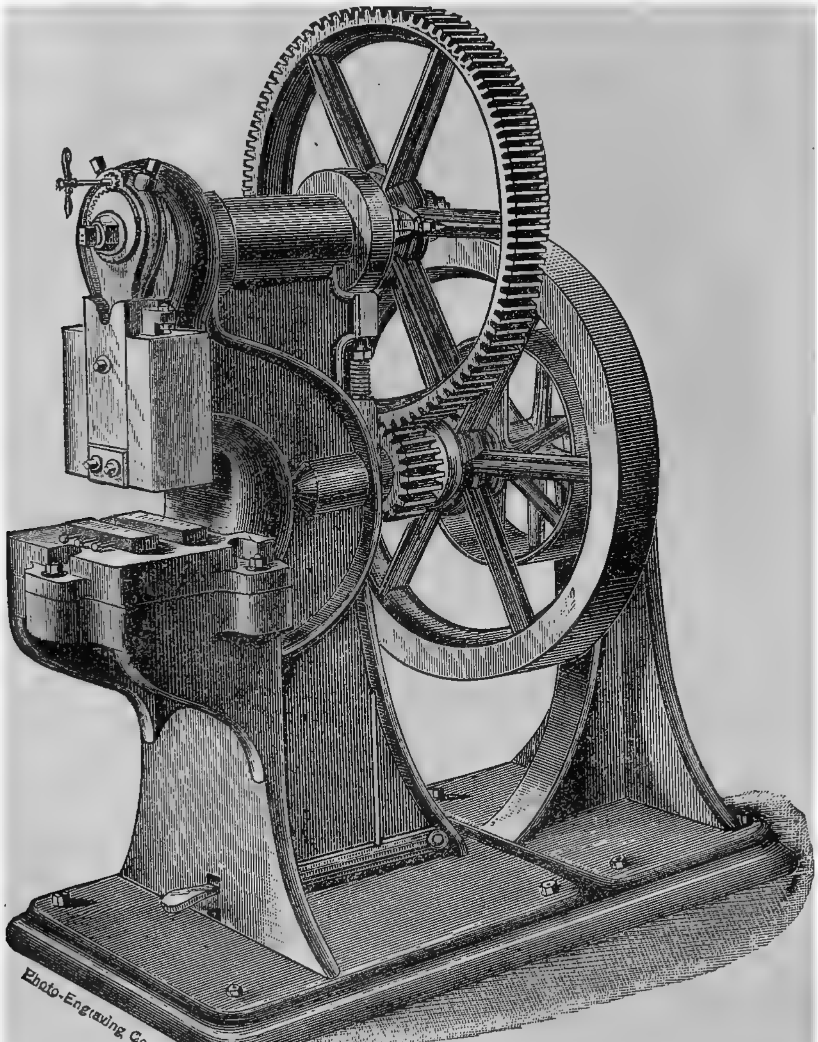


Fig. 60.

crank-shaft by the foot-treadle or by hand-lever. The fly-wheel equalizes the work of the single-acting plunger. The crank-shaft in this design is prolonged through the cap in front of the plunger, in order that the shaft may be turned by hand for accurate location of the punch before the power is applied. The punch is carried in a taper socket in the base of the plunger. Shear-plates bolt against a shoulder upon the wide, flat side. The inoperative components of crank-motion are very often taken up in a slide-block working in a rectangular opening made in the plunger, with arrangements to take up wear. Other plans use a short connecting-rod with wide bearings.

Below the punch is the abutment or die for the support of work. This is made of a diameter larger than that of the punch by two-tenths of the thickness of metal operated upon. This causes the punched hole to be tapering, but makes the extrusion of the blank more easy, and probably for that reason distresses the plate less. The cutting-edge only acts to sever the fibers for a very short distance. Below that it is the compressed metal of the work which acts to shear, and as this naturally widens as it goes down, the blank forced through is conical in shape.

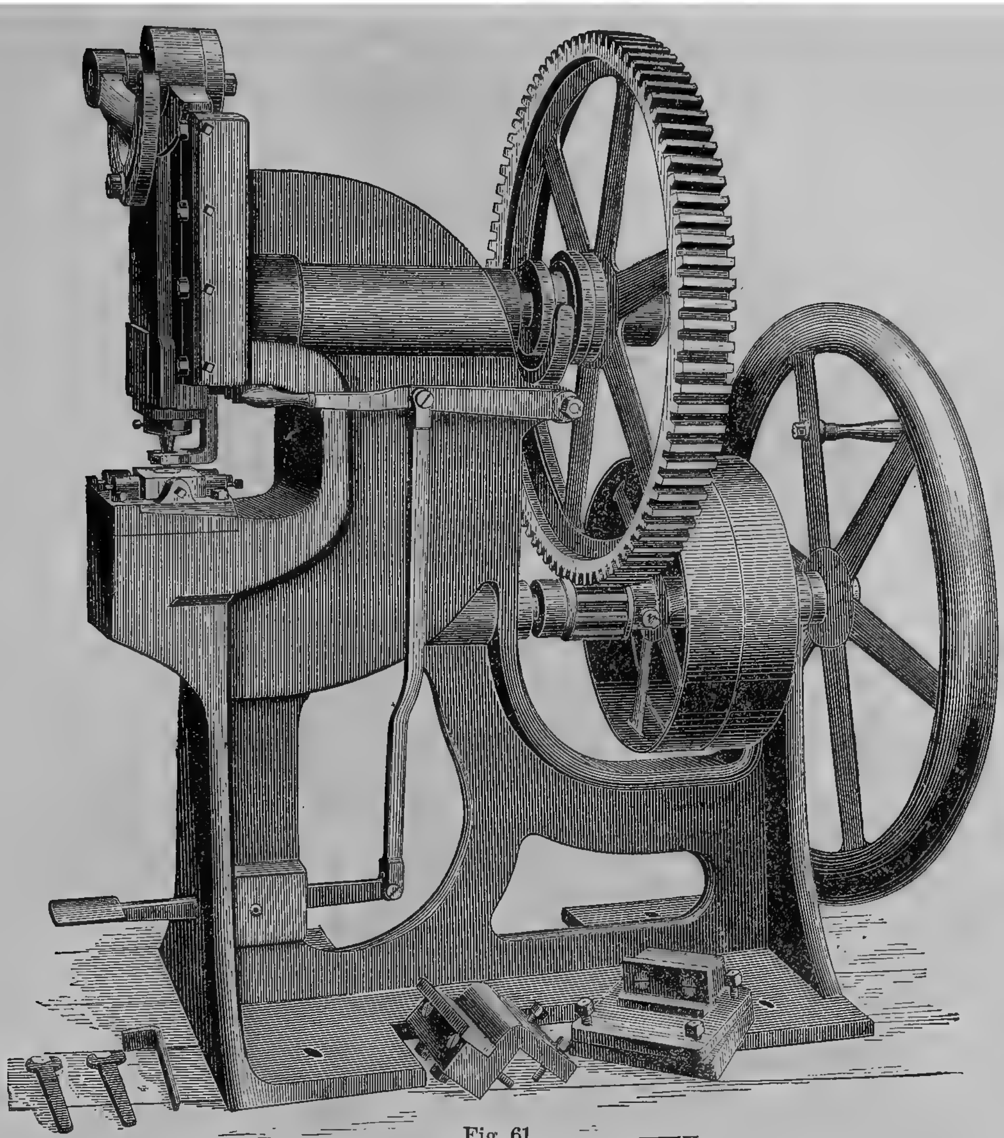


Fig. 61.

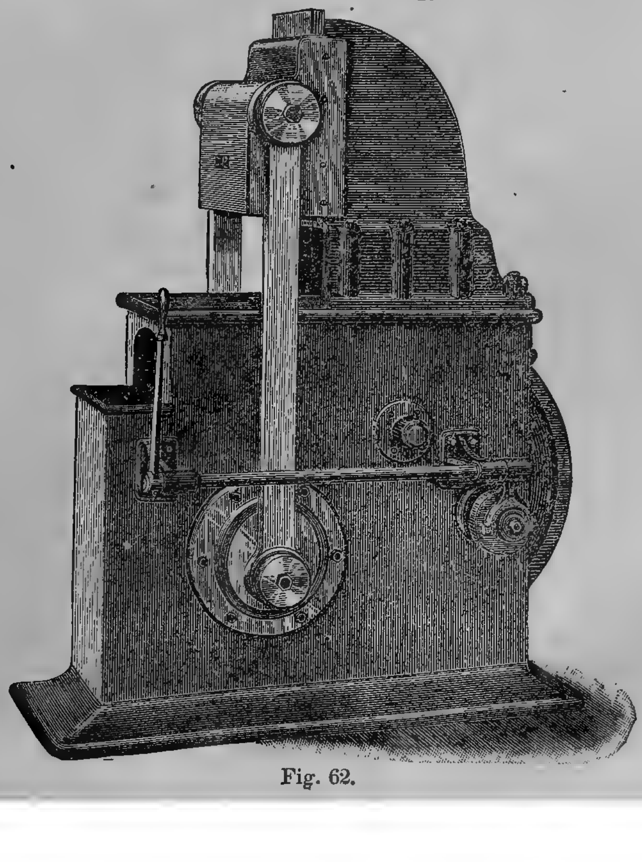


Fig. 62.

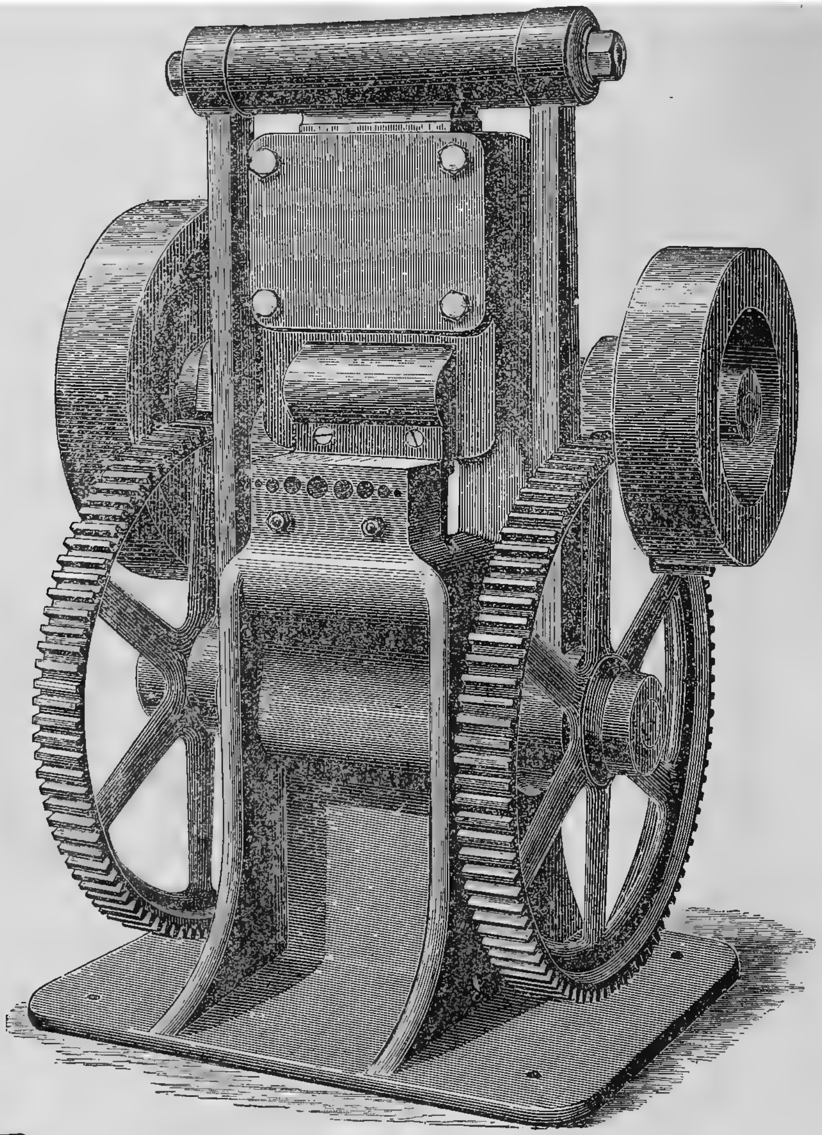


Fig. 63.

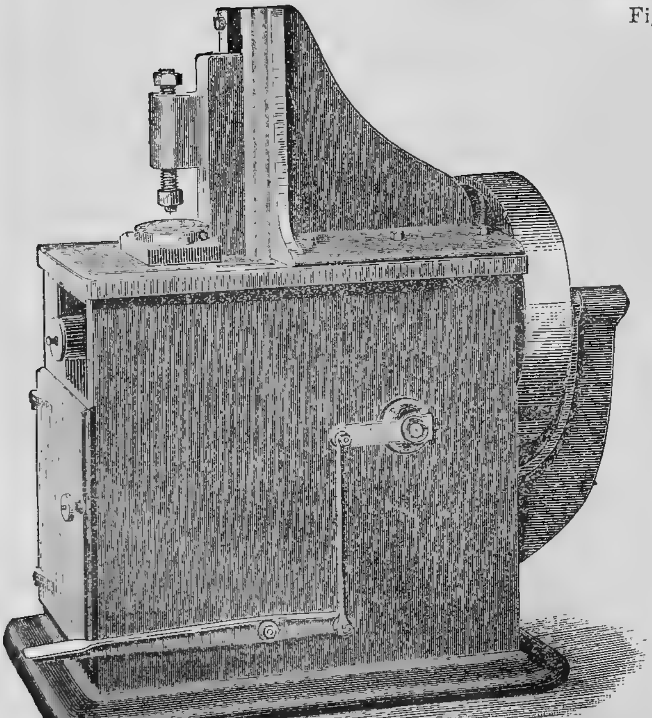


Fig. 64.

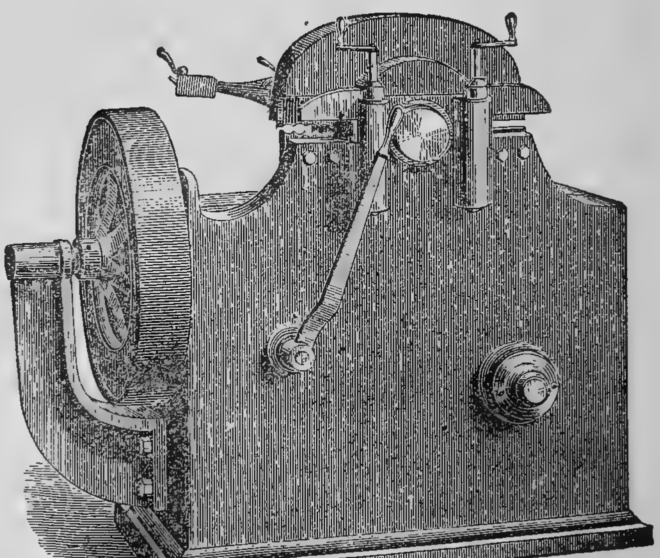


Fig. 65.

Should this conical frustum meet an abutment with a hole in it no larger than its smaller base, extra power would be required to shear this cone into a cylinder so as to fall through the hole. The abutments for shears are of a shape suited to their work. For round bars the blades should be shaped to segments of circles to take them in, else the sheared ends will be bruised and flattened when the cutting force comes upon a fraction only of the projected area of the bar. Strippers or "take-offs" are frequently applied to prevent the rise of the plate with the punch. They are adjustable vertically for different thicknesses of work. Figs. 55 and 56 illustrate the modern form of lever-punch and shear. The punch is put at the very front of the machine, which is made narrow so as not to obstruct the view. The die-seat is cut away like the horn of an anvil to enable flanged work to be handled. The holes can be punched to within one inch of the corner. In the shears the tools are fitted upon interchangeable loose blocks so that they may be converted from one use to the other, or may be adapted for any required shape. For plate the

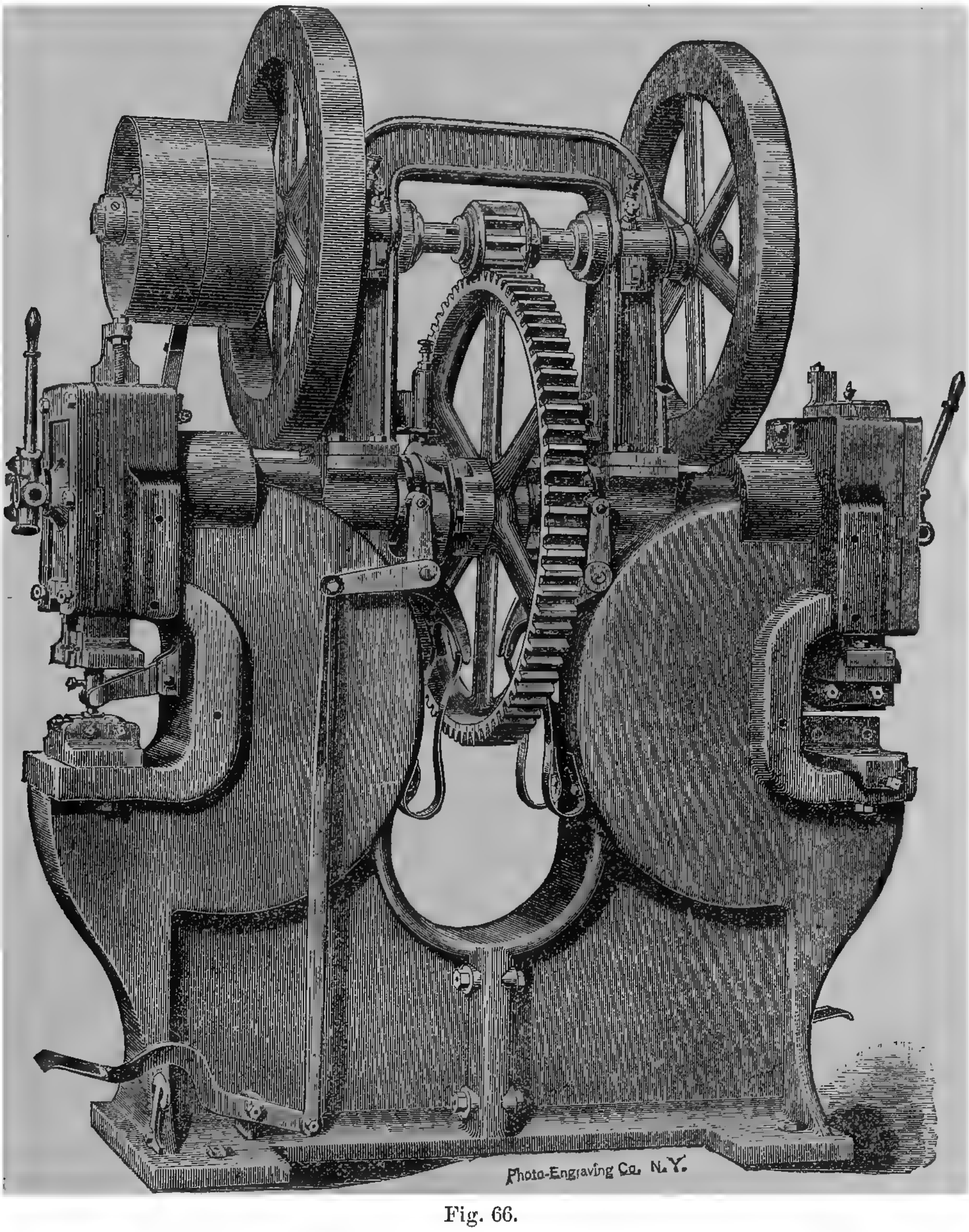


Fig. 66.

shear-blades are usually at right angles to the long axis of the frame; for bars they are parallel to it. When the plungers are guided internally the front and sides of it are left free, and proper tools can be secured to either front or sides, according to their service. By this system also the dies and blocks can be adjusted as they wear or are ground, and punches for cutting at desired intervals may be applied by adapting special blocks to hold them.

Shears for angle-iron are shown by Figs. 57 and 58, and one for bar iron by Fig. 59. The latter is arranged with its fulcrum upon an eccentric-ring, adjustable through the milled head, by which the position of the plunger at its highest point is made variable. A similar limitation may be effected by cushioning the fall of the long end of the lever. This rests upon a block of hard wood, and a thicker block permits less height of rise.

A type of light crank-punch, with connecting-rod and adjustable rise, is shown by Fig. 60. The crank-pin is

carried in an eccentric-ring, to whose face the connecting-rod is fitted. By turning this ring in the connecting-rod the effective length from crank-pin to punch-face may be varied by the eccentricity of the ring. A large size of a different design of a similar machine is shown by Fig 61.

For heavy punching of shapes from small work the type of double-connection crank-press (Figs. 62 and 63) has been introduced. The gearing is inside the hollow base and is engaged by a friction-clutch. Such a machine is capable of overcoming a resistance of 200 tons. The two connecting-rods distribute the reaction and the wear.

In the broaching-press of Fig. 64 the plunger is worked by connecting-rod from a crank upon a worm-wheel shaft. The worm turns in a pan of oil.

In the shear for flats and rounds (Fig. 65) the principle of the lever is introduced. The cutter-head is of T-shape, the center of motion being between the jaws. To the lower end of the T in the housing is attached a rod from an eccentric which is part of a worm-wheel. This wheel is driven by a worm upon the driving-shaft. This

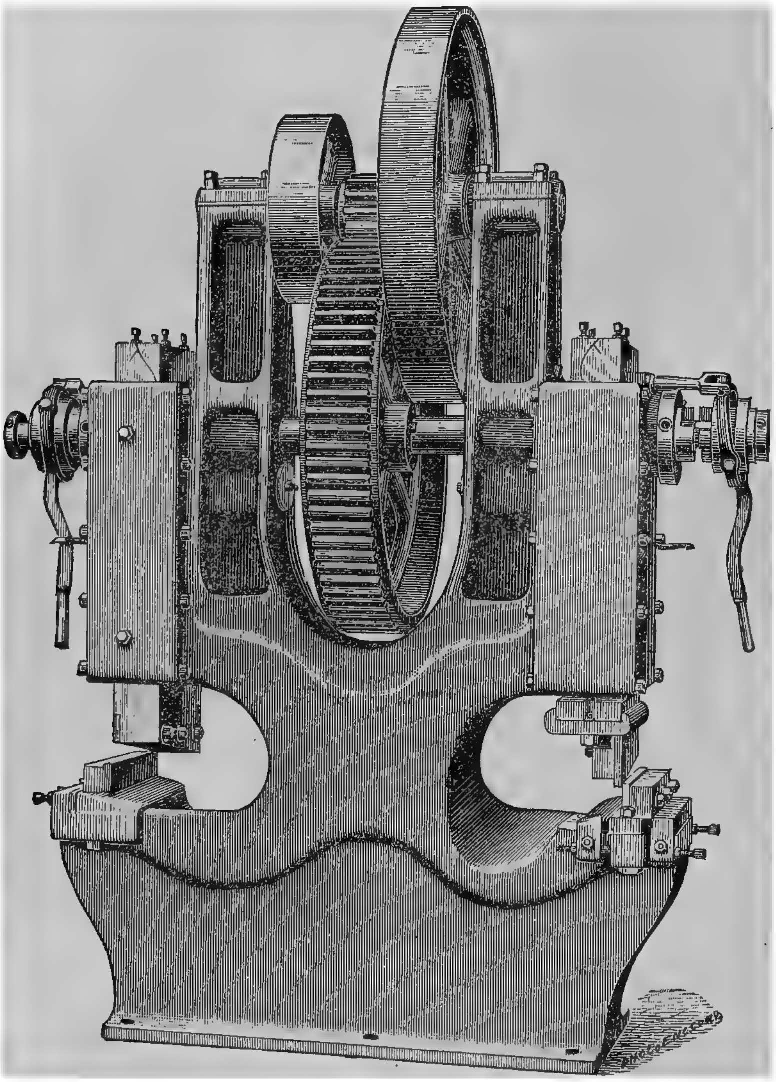


Fig. 67.

combination of screw, crank, and lever gives a compact machine of great power. By it round iron may be sheared of 3 inches diameter and flats of $1\frac{1}{2}$ inches in thickness. The old styles of "alligator" shear, where the cutting-edge is on the lever itself, is not often made for large work. Its cut is weakest at the end of its stroke when the greatest length of edge is in action.

Double machines are very much used. They have the capacity each of separate machines and take less room and power than two. Figs. 66, 67, 68, 69, and 70 show types of these. Fig. 66 shows an independent stop-motion for throwing out the clutches when the plungers are up. The forked bent lever, moving the clutch, is acted upon by the bent spring to disengage the clutch whenever the latter is released. When the treadle is depressed by the foot the clutch is engaged and this spring is compressed. When the clutch is closed the cased spiral spring above the clutch forces down a vertical roller to bear against a ridge on the clutch and keep the two halves together. This ridge is broken opposite the part of the clutch corresponding to the top of the stroke, and as soon as that

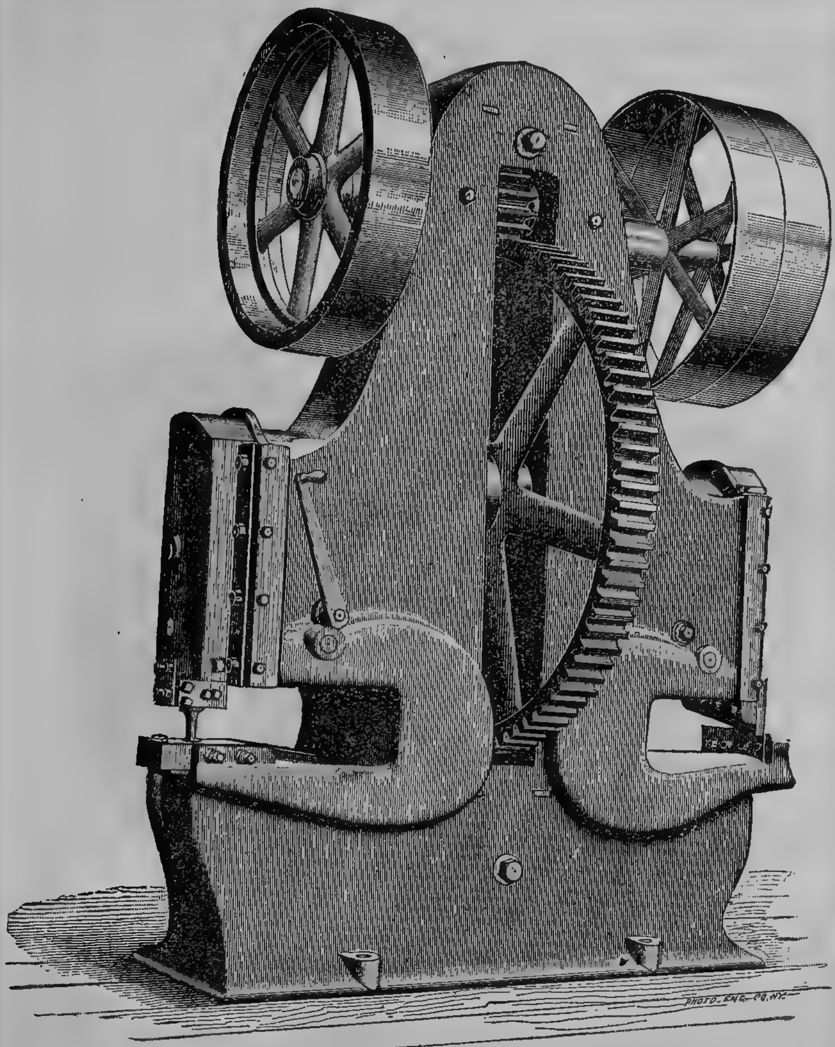


Fig. 68.

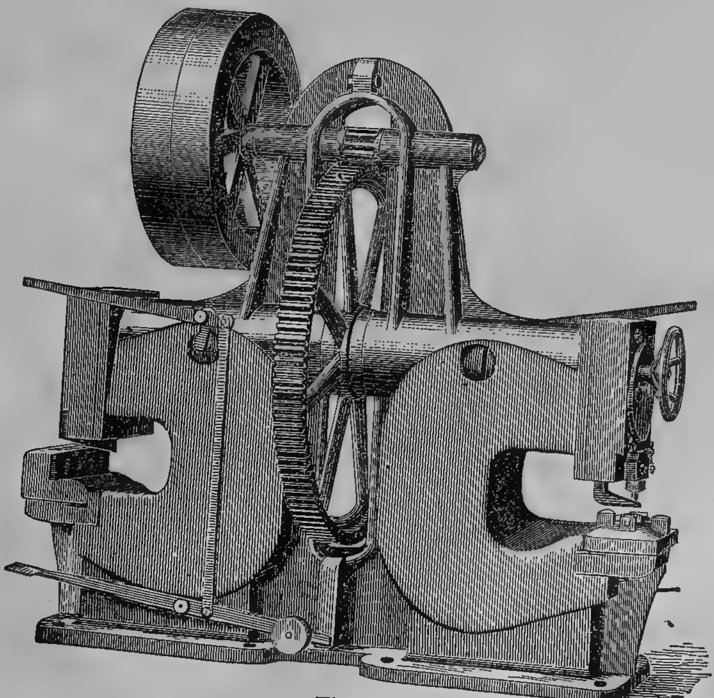


Fig. 69.

part is reached in the revolution, the treadle-spring throws out the jaws, since the vertical roller no longer holds. In Fig. 69 the fly-wheel weight is put in the belt-wheel, effecting a saving of cost of manufacture of the tool.

The same cut shows the hand-gear for bringing the punch down upon the work. These double machines are made so that either side can be worked without the other, or both at once. Often the shear side works continuously, as less time is usually required to adjust the shearing line than the circle for the punch. For reasons of compactness, these double tools are crank-machines.

For taking very long and exact cuts upon girder or ship-plate, the work should be held in place. It must also be possible to arrest a cut at a given point with accuracy. To accomplish these results the machine of Fig. 71 has been designed. The shear-blade is secured to a slide, guided vertically by the sides of the frame. Motion is given

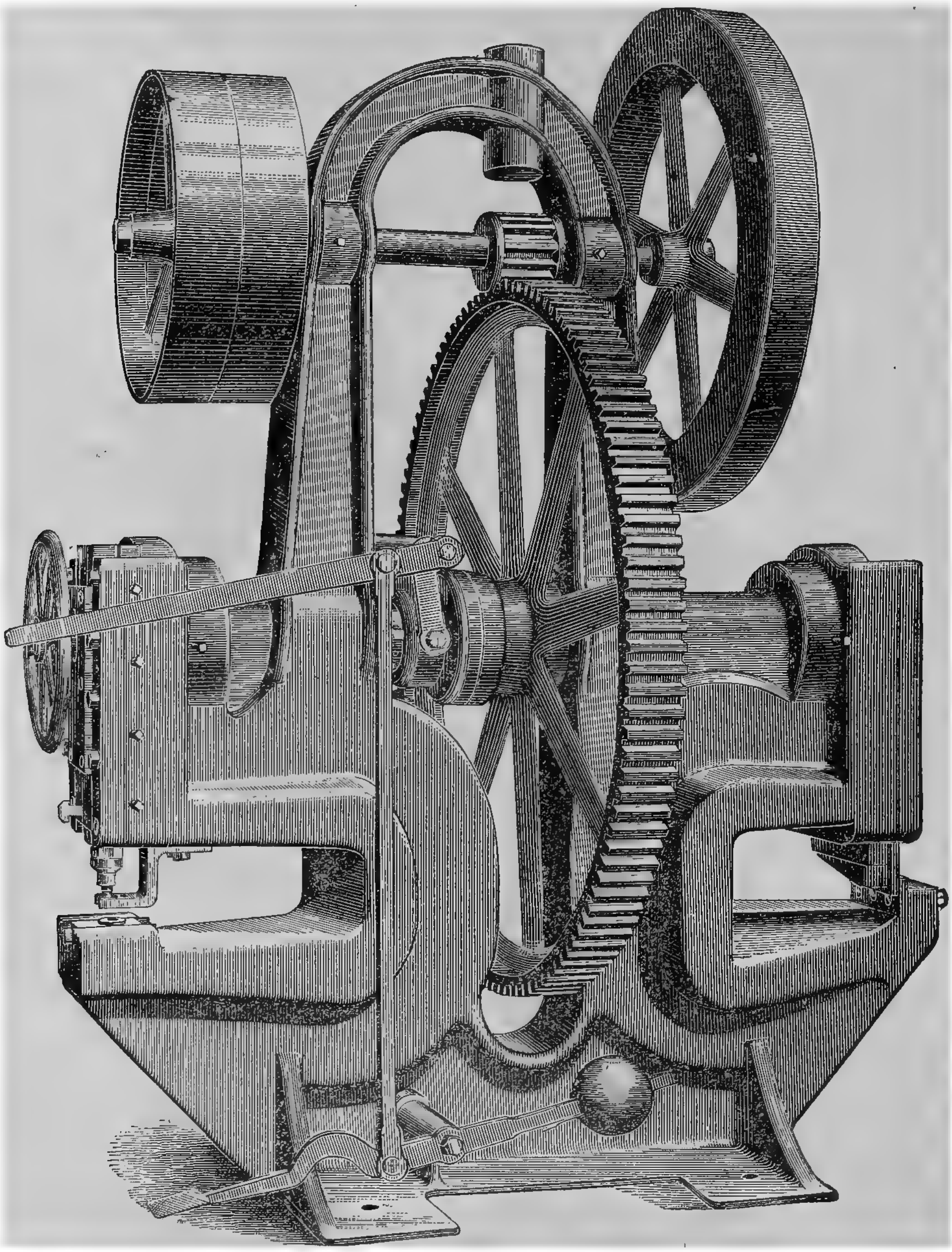


Fig. 70.

to this slide through a long solid pitman making contact-joints with the slide and the bent lever which drives it. The contact is maintained on the up-stroke by the tension-links which pass through the pitman. The driving-lever is hinged at the top of the frame, and the long end carries a toothed sector which is driven by a worm of four threads. This worm receives its motion through the pair of bevel-wheels from a belt-wheel combination of one fast and two loose pulleys with open and crossed belts. The belts can be shifted by hand, or automatically by the slide itself. The shifters can be moved by adjustable chocks. By making the overhead pulleys of different

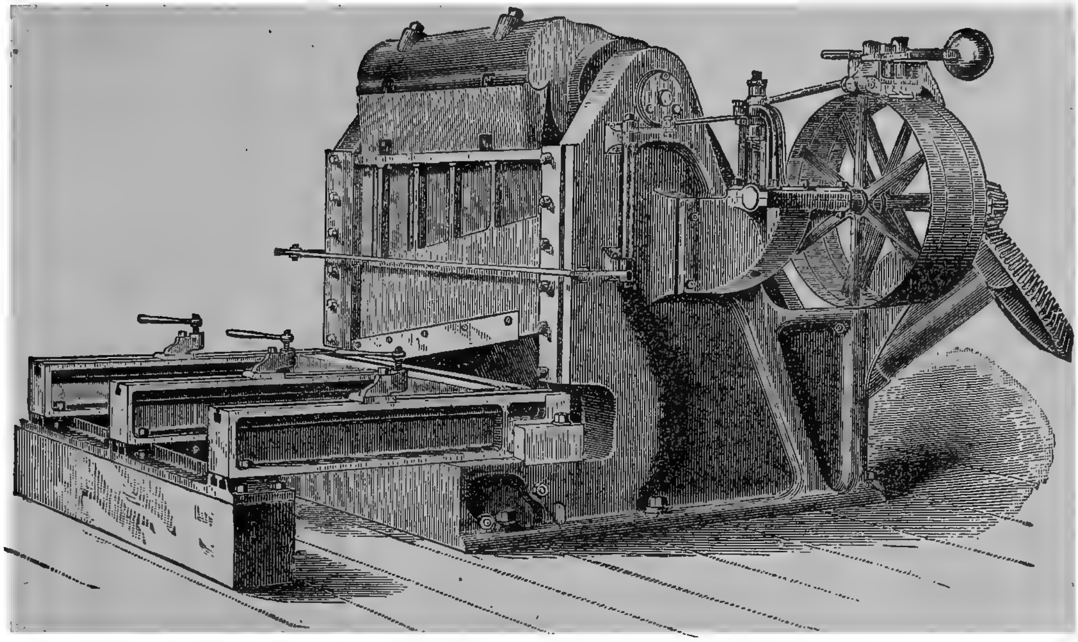


Fig. 71.

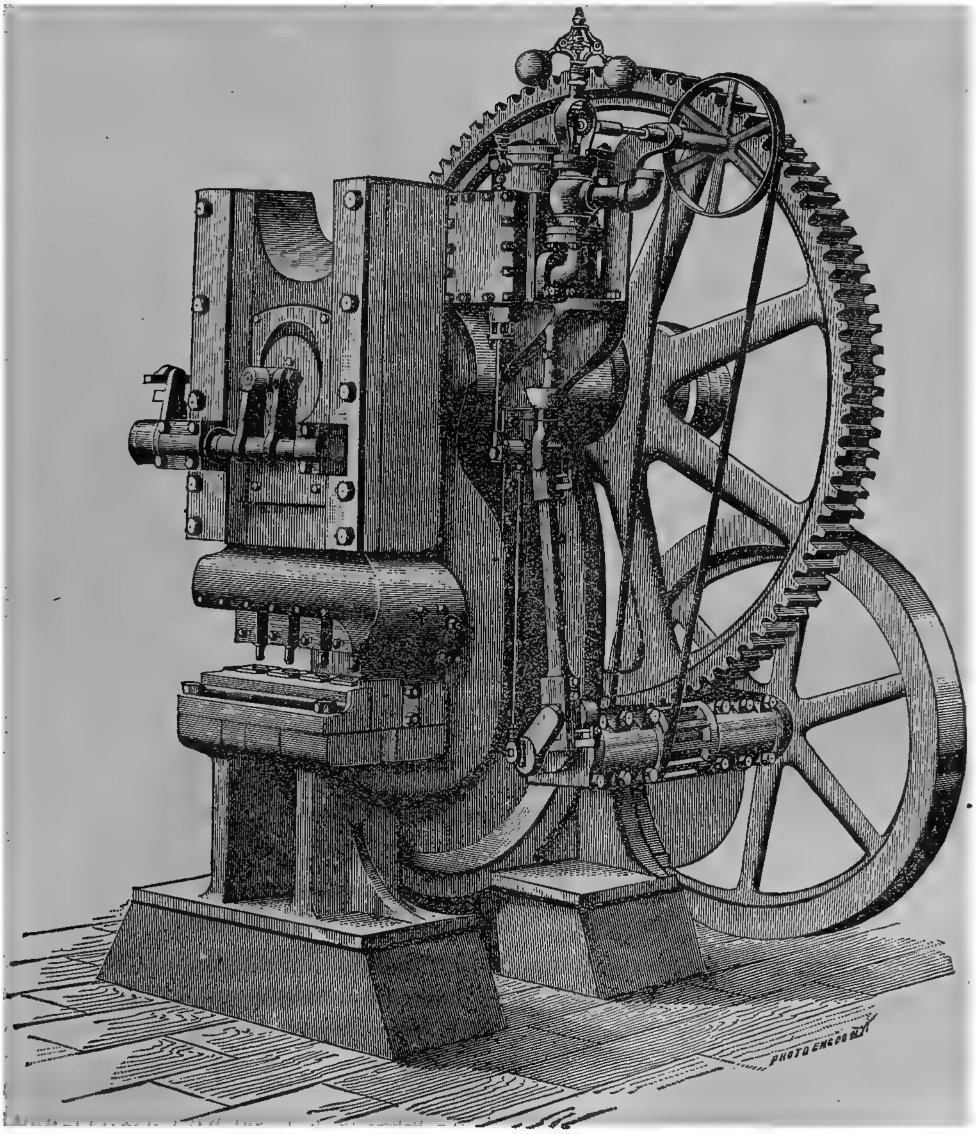


Fig. 72.

diameters, the up-stroke can be made to be more rapid than the cutting-stroke. The slide stays up until the plate is set and clamped for the next cut. The shearing-blade is here entirely under the control of the operator in every part of its stroke. Curved blades and a curved abutment may be applied with great ease for ship-work.

The wide front of the slide makes it very easy to secure special tool-blocks for multiple punching, or for punching in variable series, as in top and bottom chord webs in riveted girder-work. A combination holder may punch several spaced holes and shear the oblique end of a diagonal brace at one stroke. This can also be done on most punches with free plungers.

A crank-press of similar capacity is driven by three wrought-iron eccentrics, working upon cast-iron slide-blocks in yokes. The yokes take up wear at the pillar-bolts at the ends. The clamping-gear for the plate is automatic, being effected by a cam acting against an elbow-joint. The clutch is disengaged by a roller and side cam as in the design of Fig. 66.

Figs. 72 and 73 show two arrangements of the tools which are driven directly by steam in a cylinder which is part of themselves.

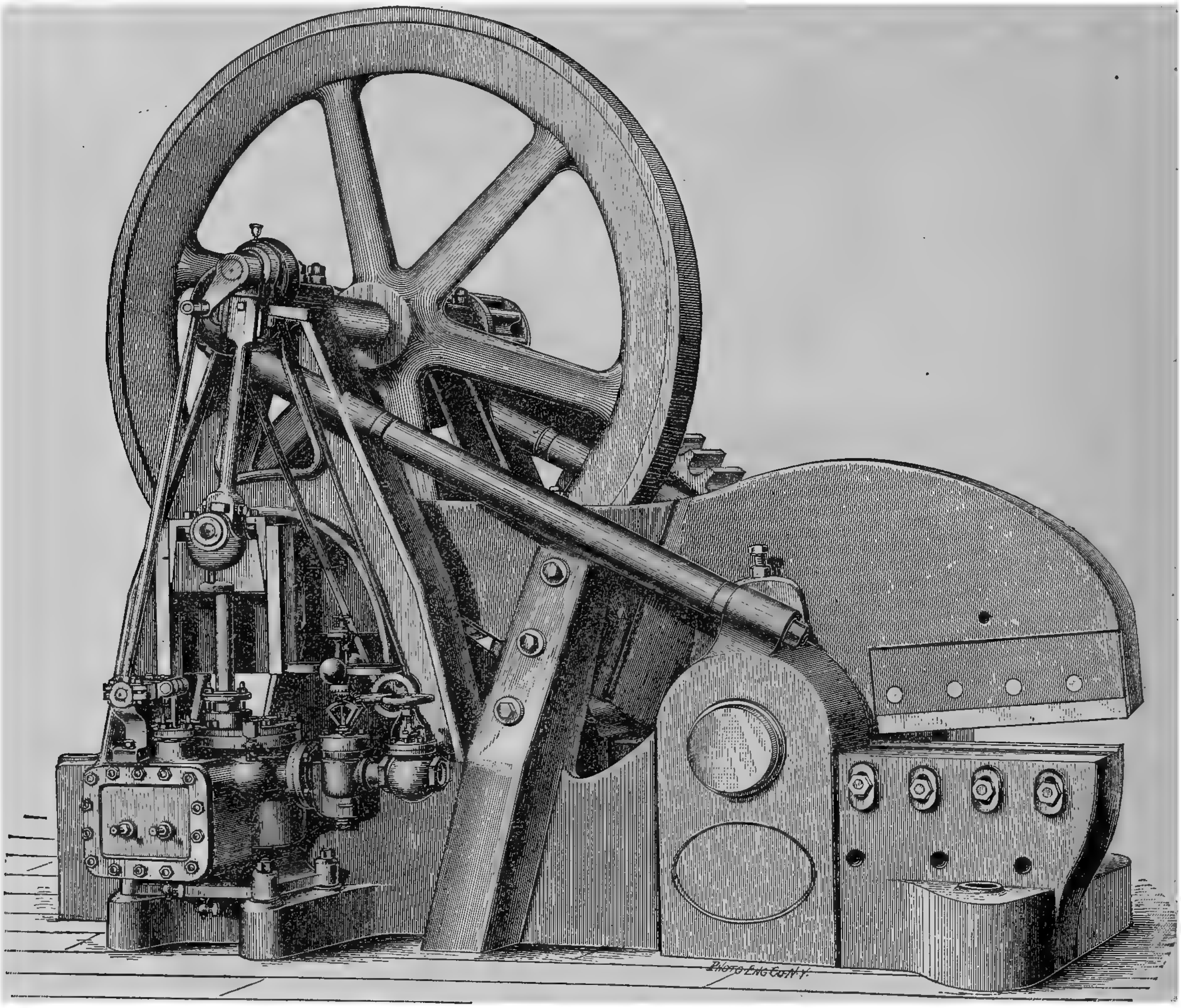


Fig. 73.

Allusion should also be made to the punches and shears which are worked directly by fluid pressure upon a piston or plunger which carries the shearing-plane at its outer end. They are not extensively in use at present, but would find their application in works which were provided with excess of hydraulic power, or in which shaft transmissions would be inconvenient.

Great economy of time in punching results from the use of spacing-tables or similar gauging devices by which the holes can be made equidistant. Without these the holes must be laid out with templet, and the plates may not be presented to the punch directly at the mark. In either case marking and adjusting to the mark take longer

than the actual perforation. These tables are carriages running transversely to the machine and arranged with a rack and different pinions, or a screw and change wheels or some other device for producing exact reproduction of standard units (Fig. 74). With such devices and multiple punches two men can cut one thousand holes per hour.

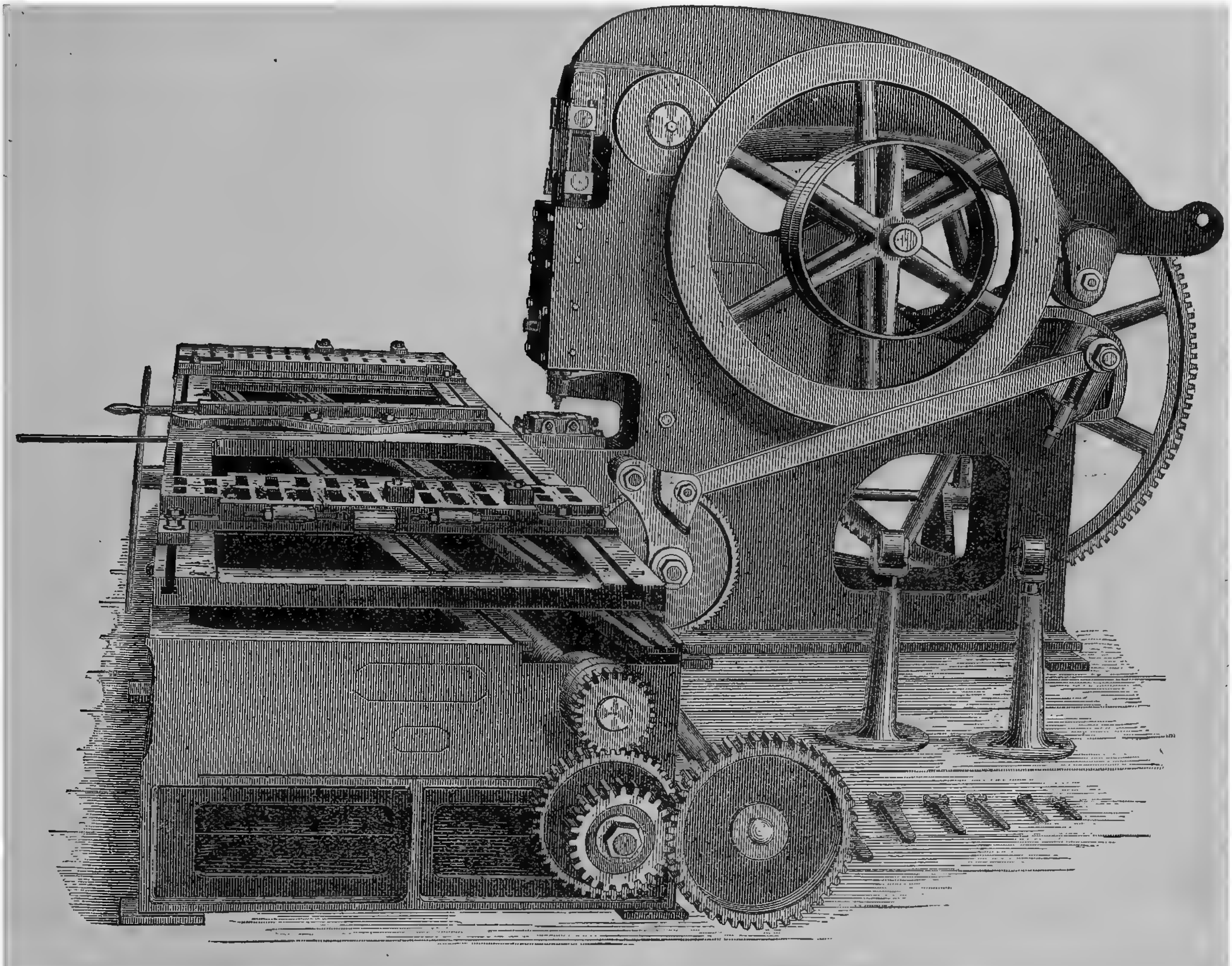


Fig. 74.

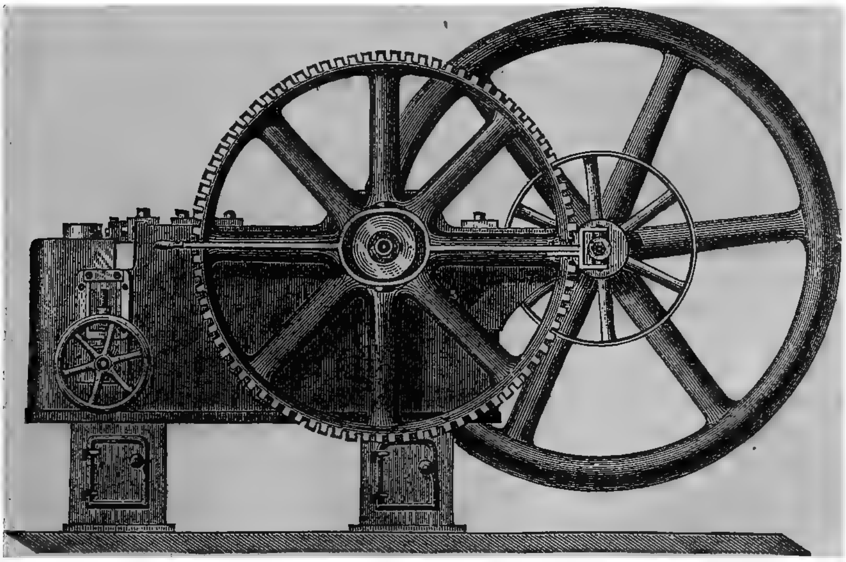


Fig. 75.

These devices can make the proper allowance for the different circumferences of outer and inner sheets in cylindrical boilers. Horizontal punches for flanged boiler-heads or fire-boxes or for angle- or tee-iron are also in use. They are called for because of the special limitations imposed by some shapes. Fig. 75 illustrates one type of such tools.

In limited use is also a type of shear for boiler-plate, the plane of whose stroke is oblique to the horizon. The idea of this is to shear the edge of the plate upon a bevel and remove the necessity of edge-planers to make ready the sheet for caulking.

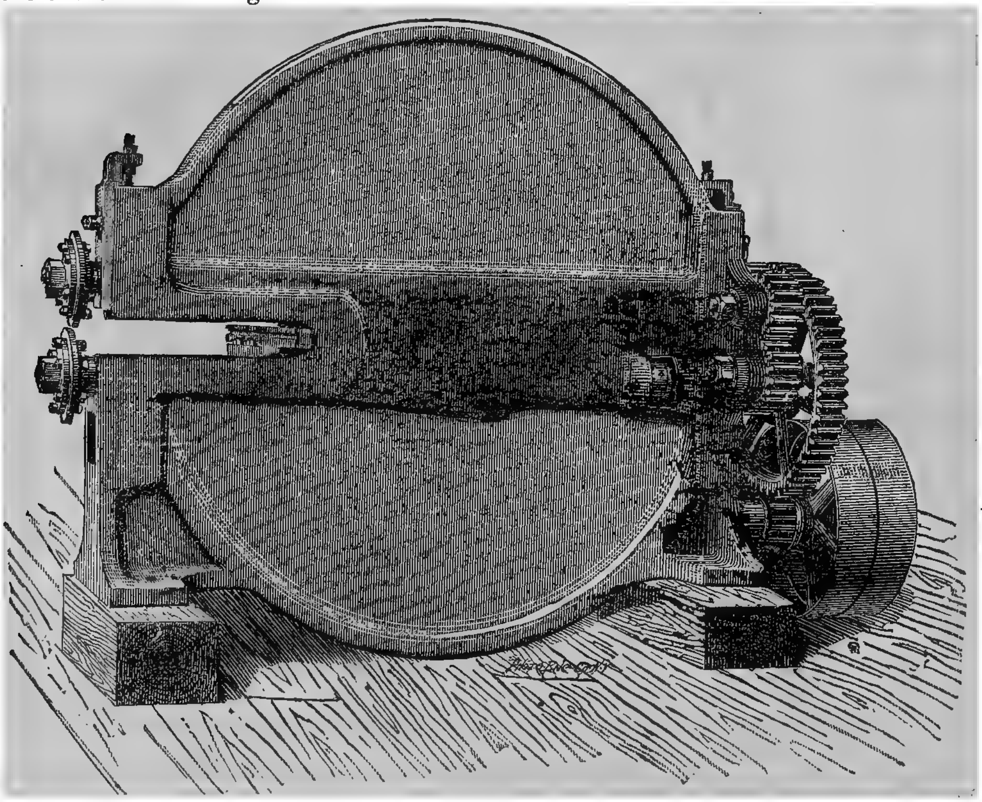


Fig. 76.

In the class of rotary shears but few large examples are seen. Two disks of steel slightly beveled and over-lapping are driven by power, and the plate to be sheared is fed against their point of contact. The disks can be brought together as they wear, both being driven by expansion gear linked to the spindles of the cutters, and can be set axially for different spaces at the cutting-point. They meet their chief application for light iron or other sheet-metal work, since they will cut a curved line. The disadvantage for heavier plate is that the knives grow jagged and chatter and mar the work. They are not very extensively in use at this date.

Fig. 76 gives an illustration of one design for large work, up to $\frac{5}{8}$ of an inch thick.

Punches and shearing-presses are extensively used in drop-forging work for trimming or broaching the work after leaving the dies. They are also used to produce a cold-press finish upon pieces which would otherwise have to be milled. The double-connection presses are used for this class of work. In the sheet-metal presses, and in those used for the manufacture of drawn goods, shearing is also done, but these tools are beyond the province of this discussion. These tools belong either to the crank class or to a special class of roller-cam presses.

§ 15.

C.—TOOLS ACTING BY PARING.

To this class belongs the majority of the tools of the finishing- or fitting-shop. It includes all those in which the desired figure is produced at the working point by the scraping or cutting action of a wedge-pointed tool. Since they act upon the cold metal and remove relatively small amounts of material in the cut, these tools are much better adapted for working to exact dimensions than those acting by compression or shearing. They can also produce an ornamental finish upon the material which they shape. These features adapt them for the needs of the shop from which the completed work is to be delivered.

Paring-tools belong to two classes. The first includes those in which the relative motion of tool and work is circular or spiral. These can only produce surfaces of revolution, and include lathes, drills, and boring-machines. The second class includes those in which the relative motion of tool and work is rectilinear. These will produce plain surfaces by planers, shapers, and slotters, and also curved surfaces made up of straight line elements by the two latter tools.

The greater part of revolving machinery is made up of surfaces of revolution. The cylinder of these is by far the most important. The lathe will therefore be discussed first.

§ 16.

HORIZONTAL ENGINE LATHES.

The essential parts of a lathe are the bed, the head-stock, the tail-stock, and the arrangements for holding or supporting the tool. This latter device is called the slide-rest or carriage.

It is the primary function of a lathe to produce a truly cylindrical surface, with plain heads perpendicular to the axis, upon the rough material presented to it. The motion of the point of the tool must therefore be truly parallel to the axis of the tool; this latter must be a true straight line, and the secondary motion of the tool must always be at right angles to this line.

The first condition must therefore be stiffness in the bed of the tool. Under the strain of the cut it must not bend downward nor yield laterally. The bed is usually of cast iron, made of two girders of approximate I-section, whose flanges shall give the necessary vertical strength. The newer tools are built with much greater depth of bed than the earlier forms had. To secure lateral stiffness, the two girders front and rear are connected by interior cross-girts about 2 feet apart. These bind the two sides together, and are put near enough to each other to avoid any spring between them. Small lathes are mounted upon legs at sufficient intervals; the lathes of larger swing must be bedded upon a foundation upon which the bed rests directly.

Upon the top of this bed will be the guiding lines for the movable tail-stock and tool-carriage. The finished upper surface of a lathe-bed is called its shears. There are two types of practice with reference to the form of track upon which the sliding parts shall move. In one type the shears are finished off flat, and in the other there are four parallel tracks upon the shear, of inverted V-form, truncated on top.

The advantages of the flat-top shear are its extended bearing surface on the bottom of the carriage and the ease with which the true flat surface may be produced. The large surface reduces the pressure per unit of area, insuring lubrication, and therefore retarding the wear of the sliding surfaces. If hollow places are worn in the shears, the tool-point will fall at those points, producing untruth in the cylinder which is being cut.

The objections to the flat shear are that the tail-stock must move easily in the opening between the shears, that it may be adjusted for work of differing length. For this ease of motion some play must be left between the two sides of the bed and the guiding surfaces of the tail-stock. This play will be enough to vitiate the truth of the cylinders cut by the lathe. Its effect has been avoided by one designer, whose lathes have a V-track upon the under side of one shear. The clamping device fits over this V from below, and when the tail-stock is clamped it is

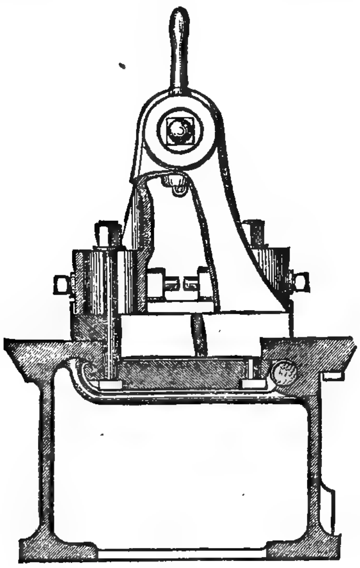


Fig. 77.

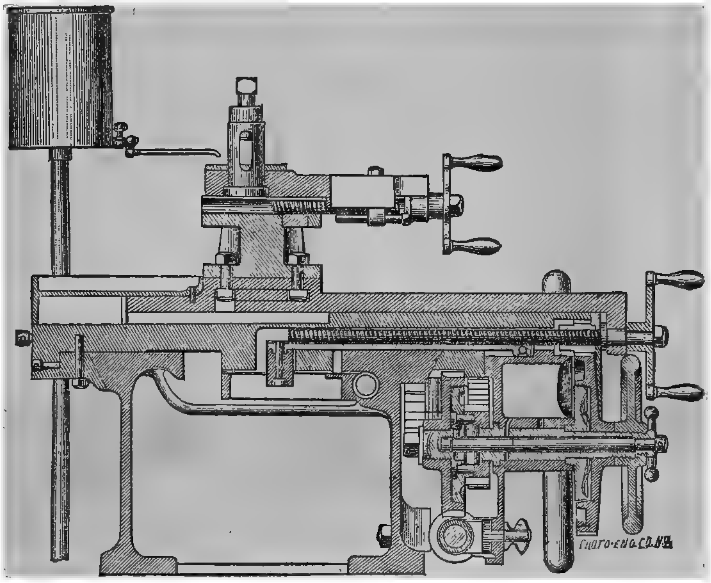


Fig. 78.

certain to be drawn always into the same relation with this V, and the axis of the lathe will be always in one line (Fig. 77). In other designs the stock is kept up to one side by adjustable brass taper gibs, reducing the lost motion to a minimum. The guiding of the tail-stock by the inner edges of the shears is practically universal in the flat shear designs. The carriage or saddle carrying the tool-holder will be guided upon the outer edges (Fig. 78). Otherwise, the wear on the surfaces nearest to the head being the greatest, the untruth of the axis would be increased by the lateral wear due to the carriage-motion.

A second objection to the flat shear is that it opposes its strongest resistance to the vertical components of the strain on the tool-post, while the horizontal components are only taken up by gibs. In turning large work upon a

small lathe, where the point of the tool is over the shear, the vertical components will be the greatest. Upon a large lathe also, where the shears will be wide and the carriage and attachments heavy relatively to the strain of the cut, the vertical components will be in excess. But in a lathe cutting work of small diameter, whether facing, boring, or turning, the strain on the tool-post is oblique, passing downward at an angle from the center which varies with the swing of the lathe, and will average perhaps 30°. This strain tends to force the tool downward and outward. The downward strain is resisted by the broad shear; the lateral strain comes upon the gib at the rear only (Fig. 78). This latter strain is not opposed by surfaces at right angles to it nor by surfaces of large area. The freedom for sliding upon the fitted surfaces must also be in this lateral direction, which at the same time is the direction in which untruth will produce the greatest effect to mar the work.

The further objections which have been urged against the flat shear that they make it harder to move the carriage, and that chips from the work get ground into the ways, may be dismissed with a word. The ways will not be clogged when the tool is taken care of as it should be; and a new form of flat shear with a lower step for the tail-stock motion is an effectual preventive of the latter difficulty, even if it were a real one, with shears in one plane only.

The advantages of the V- or track-shears consist, first, in its opposing a resistance normal to the oblique pressure due to a cut on a small cylinder. Upon the top of the bed are four raised rails, of inverted V-form, truncated on top. These V's are of varying angle, around 60° as a mean. The sides of the V's which face the

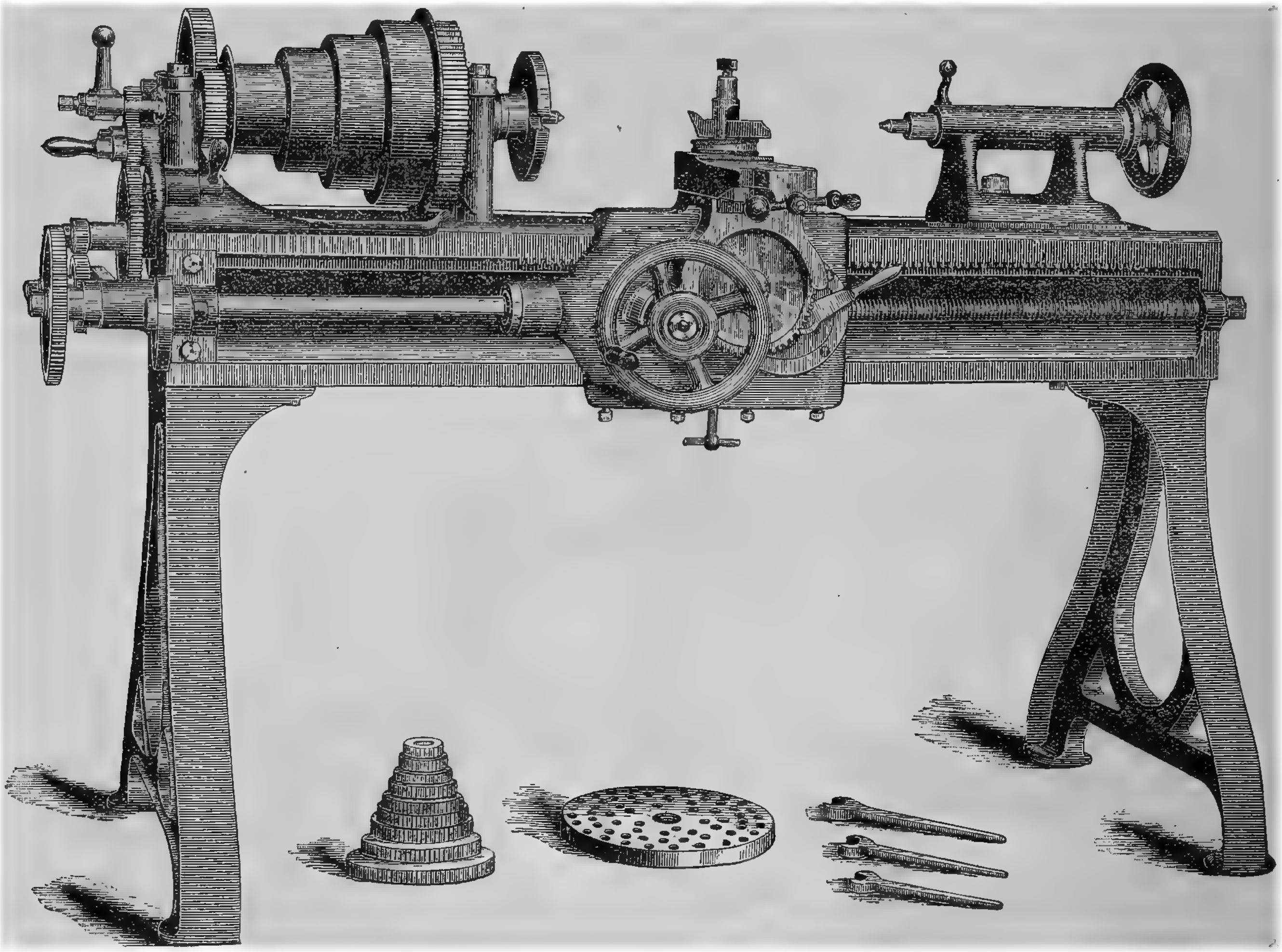


Fig. 79.

back of the tool on each shear are about normal to a strain which presses down obliquely at an angle of about 30°. In some cases of large lathes the angle of the track is about 90°; in others it is 75°. The carriage is carried upon the outer pair of V's, resting upon them in grooves planed in its lower side. It is kept from rising by gibs under the flange of the bed-top, and its own weight secures all the freedom required for ease of motion, without lateral play. The tail-stock travels by similar grooves upon the inner pair of V's, thus securing at all times a perfect alignment with the head-stock. Moreover, the clamping of the tail-stock upon the V's holds the frame from spreading, and acts as a rigid cross-stay where the strain of the dead-center comes. Its freedom of motion is secured by its vertical yielding only. When the tool is at work, therefore, is the time when all its parts come most exactly into line, provided the shear-tracks are perfectly parallel.

Against the V-shears stand the diminished surface for wear by vertical strains, the danger to them from blows, the difficulty of keeping them lubricated, and the expense of accurately fitting them to parallelism and to the grooves in carriage and poppet-heads.

The V-shear is the characteristic American type. It is preferred among all the New England manufacturers, where the tools are built for general work and for jobbing, where small diameters will predominate. Around Philadelphia the flat shear is popular, where the tools are built more for large and heavy work, where the downward pressure will be in excess. For axle or shafting lathes and others, where one diameter is to be prevalent, the shears may be so proportioned as to bring the bulk of the strain vertical, and the flat shear will then be preferable. For large tools in best practice, the moving parts will travel upon three shears instead of upon two only (Fig. 119). This may reduce the swing of the tool slightly, but the gain in stiffness more than compensates for the loss.

One form carries the slide-rest upon the front of the bed only (Fig. 79). This gives large swing over the shears. The carriage does not wear the track of the tail-stock.

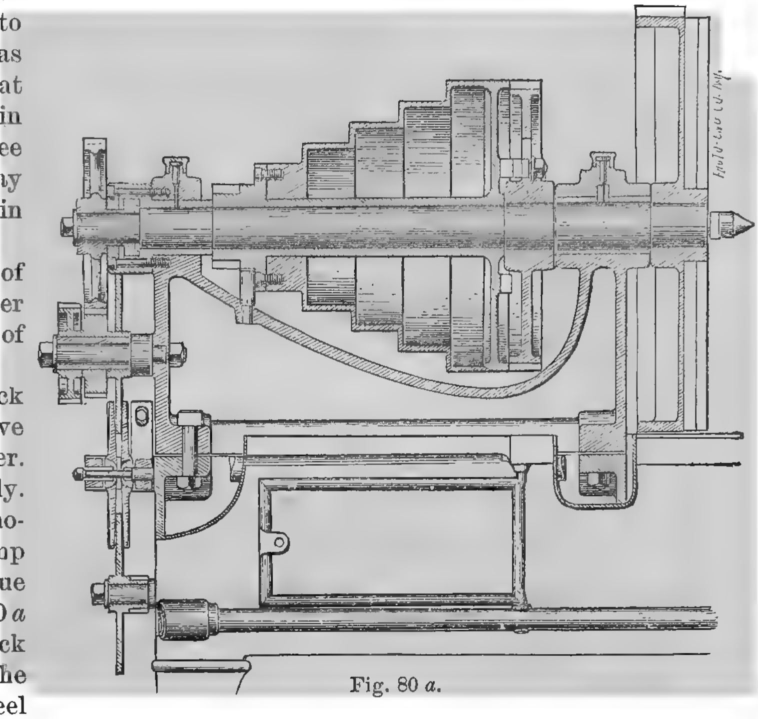


Fig. 80 *a*.

Upon the bed of the lathe will be the head-stock and tail-stock, the former carrying the rotating or live center, and the latter the stationary or dead-center. The head-stock will be bolted to the bed securely. The tail-stock must slide along the bed to accommodate work of differing lengths, and should clamp securely fast to the bed with the center in the true axis of the tool. For lathes of small swing Fig. 80 *a* illustrates the general construction of the head-stock in section and in plan. The essential feature of the head-stock is the live-spindle. This is made of steel up to certain sizes, hardened and ground true. Upon the truth of this spindle depends the truth of all work done in the lathes. Any errors in it will repeat themselves, especially in work chucked to the face-plate. In small lathes this spindle turns in hardened steel split boxes. For the larger sizes composition boxes, and cast-iron boxes with babbitted pockets, divide the manufacturers about equally. Many would prefer cast iron alone if they could always insure lubrication. The front journal is always made cylindrical in best practice. Conical journals are apt to "seize" from some variation in temperature and will become cut out of true. Older practice had a collar upon each side of the journal. Newer practice leaves off the outer collar, and the most advanced designers leave off both shoulders and control the end play of the spindle from the outer end. In this system the front or inner journal controls the sidling or lift of the spindle only, and any changes of temperature cannot impair the fit or cause lost motion endwise. To take up the thrust of the tool against the work when facing or when feeding heavily toward the head it is necessary to have some sort of step at the outer end of the spindle. Where the single-shoulder system is in use the rear end turns in a cylindrical box, which is closed at the outer end. Through this closed end passes a hardened steel screw whose axis coincides with that of the spindle. This tail-screw either bears directly against the hardened end of the spindle or else through a washer. The washer is sometimes a disk of hardened ground steel, but in most frequent practice a washer of rawhide is employed. This causes less difficulty from the danger of cutting if it gets dry by accident, and is increasingly popular. The difficulty is the lack of uniformity of the hide. The tail-screw is secured from working loose by a jam-nut against the box, and any degree of closeness of fit longitudinally is obtainable. One designer uses a washer of vulcanized paper fiber, and one uses composition. There are advantages connected with

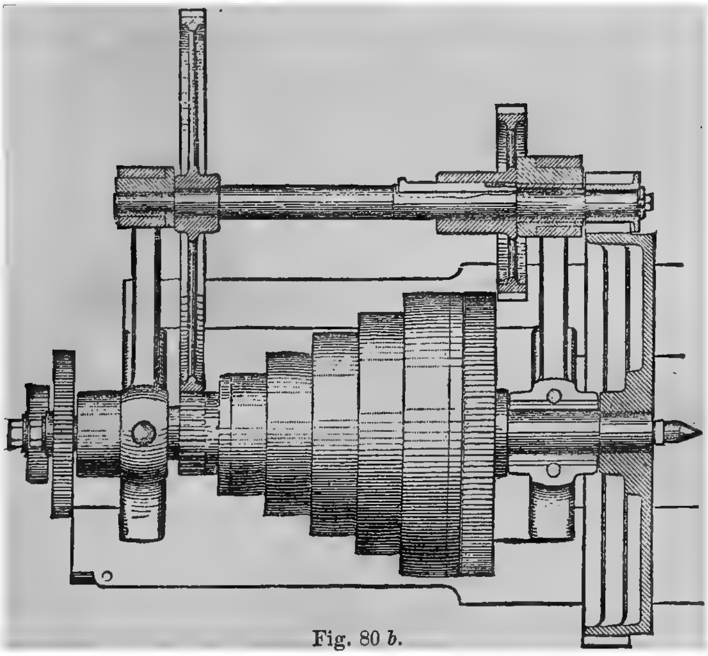


Fig. 80 *b*.

the practice of confining the spindle from end motion in both directions from the tail end. A type of such designs is shown by Fig. 80 *b*. Near the end of the spindle is secured a hardened steel ring or collar, which is ground true and runs between similar washers, from which lost motion can be taken up. When kept well oiled by keeping an oil-cellar full these disks run without liability to stick or jam.

To insure that a lathe-spindle shall always run true, even after wear has begun, beside taking up the end play, is the object of the spindle-journal invented by one of the New England builders. The box is a split cylinder of gun-metal, with conical screw-threads cut on the outside at the ends. Two cheese-nuts fit upon these screws, and by turning them down the box is closed up concentrically upon the journal. A wooden pin prevents the nuts from closing the splits too closely. At the rear box, beside this arrangement, is a bearing-step for motion in one direction, and a pair of jam-nuts bearing against a washer prevent motion in the other direction. The chief point with regard to these thrust bearings is that they have sufficient area. Otherwise they will be apt to wear into rings and cut the surfaces. One designer using steel disks makes them a little smaller than the cell in which they lie. They will turn freely, and yet, being eccentric to the spindle, they must be worn flat uniformly, and will tend to bring up oil from the bottom of the cell upon the step. The advantage of discarding the prevalent step-screw is that the pinion for the feed-gear for the carriage can be put directly upon the end of the spindle. Otherwise this pinion must be inside the head casting, and the latter must be perforated to allow an idle spindle to pass through it, with gears outside and inside. This weakens the head and prolongs the span of the spindle between journals. The alternative way, retaining the step-screw, is to mount the latter upon a separate cross-piece at the tail, supported upon pillar-studs tapped into the end of the head. The Pond box (Fig. 81) permits the spindle to pass through freely, since the thrust is taken up on a steel ring shrunk on the spindle. A hollow steel sleeve flanged at the inner end screws against this ring through the end of the box. The box is hollowed into a chamber around the ring and flange, which is filled with oil up to the horizontal diameter. For the largest sizes of lathes, where the spindle will be massive enough to be made of cast iron, the thrust will be taken up by the collars upon it. The faces of the boxes will often be recessed and babbitted in these designs. One designer of light lathes (Fig. 82) uses a cylindrical box externally, so that the box may be replaced when worn, without replaning the head, to bring the spindle in the center. The boxes are split, and a conical-pointed screw in the crack prevents cramping on the journals.

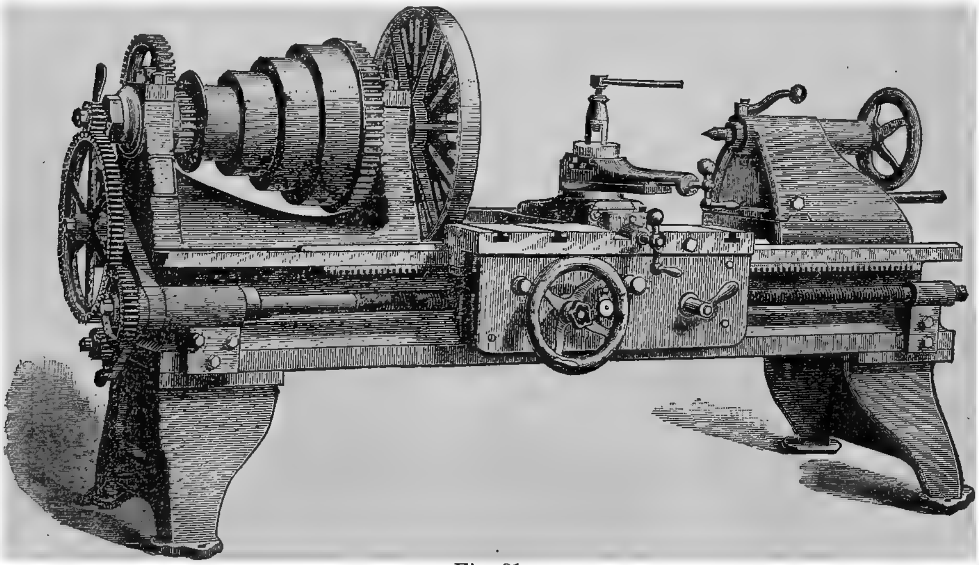


Fig. 81.

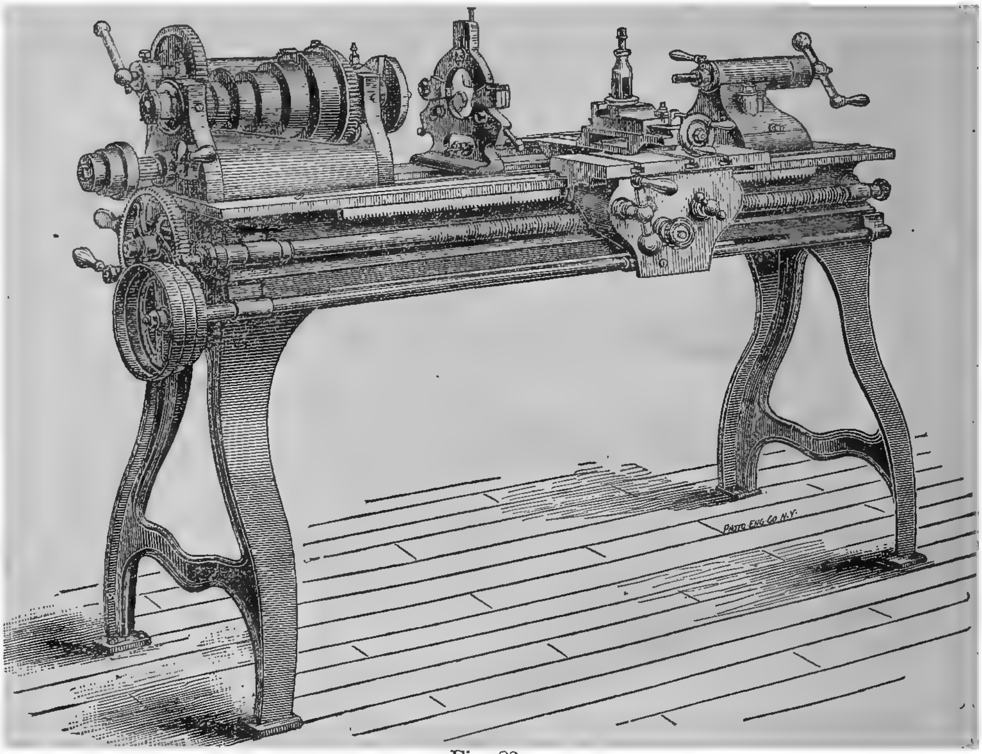


Fig. 82.

The shape of the casting in which the boxes for the spindle are supported will be seen from the various cuts. The top surface curves upward toward the tail, giving effective depth to resist the strains at that part. In one design the hollow underneath the casting is braced by stiffening ribs. The differences required for the lathes of larger swing are solely due to their larger size. The aim of the recent changes of design has been to secure the greatest stiffness and strength against the strains to which the head is exposed.

Upon the live-spindle turns freely the nest of cone-pulleys. This is a series of belt-wheels of different diameters, made necessary by the variety of work to be done upon the tool. The cutting-edge of the tool can act at different speeds upon brass, cast iron, wrought iron, and steel, and a given speed must not be exceeded upon the circumference of cylinders of very different diameters. This variation is most easily accomplished by the use of two nests of cone-pulleys, one on the counter-shaft and the other on the tool. The two nests are complementary, with the sum of the diameters of each pair in the series equal to a constant quantity. The same belt can be used on all, but it

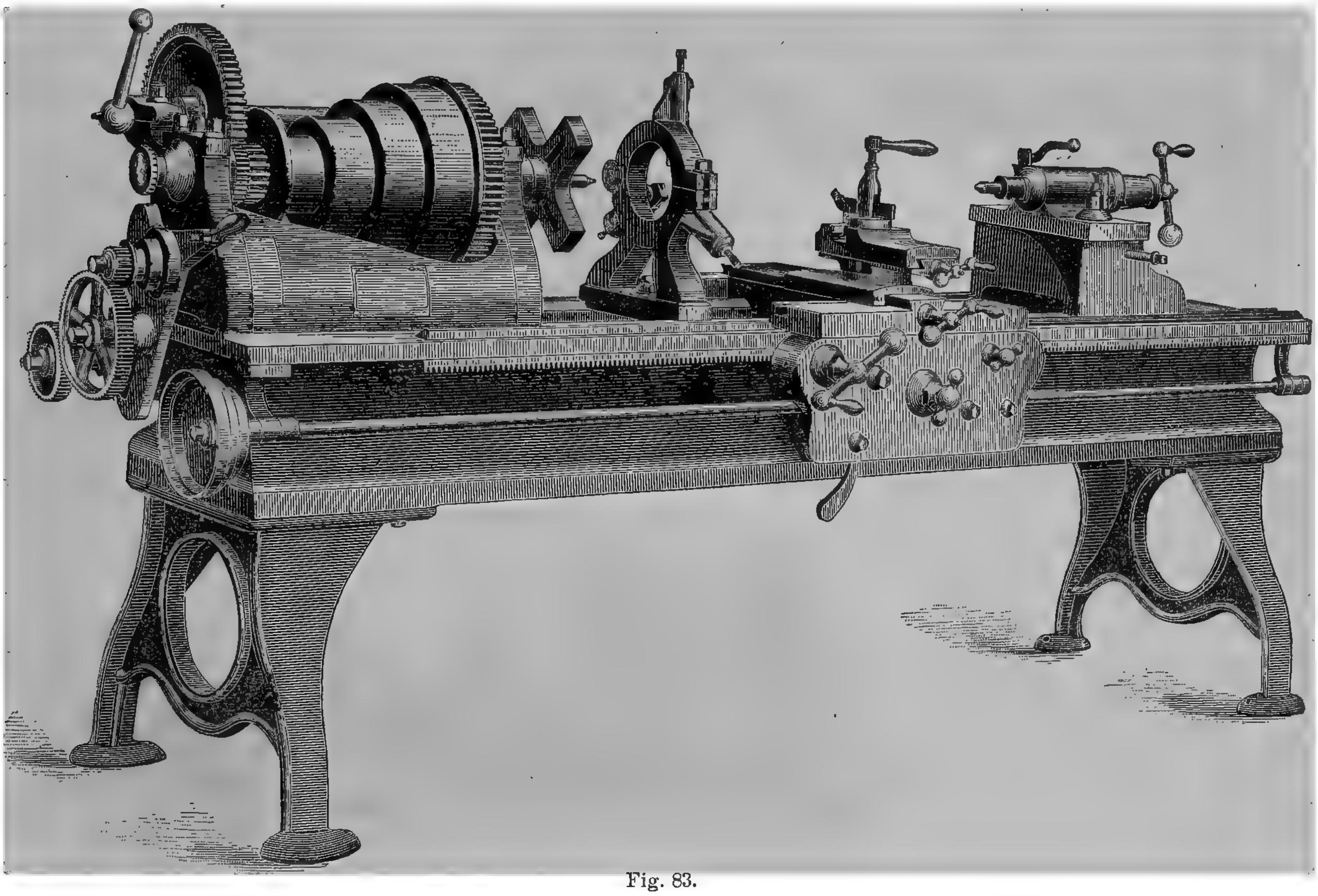


Fig. 83.

will run at different speeds, and therefore produce different speeds of rotation of the work. There are usually four pulleys in the cone. Three only are put on the small sizes, while the very large have five, six, or seven. The faces of the pulleys are most frequently flat; those of a few builders are made crowning. The pulleys are made in one hollow casting, with a long sleeve for the spindle to pass through. The end of the sleeve in larger cones is braced to the large pulley by a spider cast with the cone. For case of fitting, the sleeve is often cut away in the middle of its length and bears on the spindle at its ends only. The pulleys are sometimes turned on the inside, to insure a perfect balance and smooth running. At the small end of the cone a flange is often put to prevent the belt from running off into the gears. If no flange is used, a guide-pin may be put below, into the casting, to serve the same purpose.

Beyond the flange is a small pinion, either cast as part of the cone or secured to it by screws. This pinion is to drive the "back-gear", or "double-gear", as it is called. This consists of a shaft holding a large and a small gear-wheel, which may carry the motion around the cone-pulleys to a large gear in front of them. This large gear is secured to the live spindle. It will be seen that when the small gear on the cone-pulley drives the large gear on the back-gear shaft, the latter will move at a speed much lower than that due to the cone-pulleys. When again this motion is further reduced, because a small pinion on the back-gear shaft drives the large gear on the spindle, the speed of the work will have been very much lessened. The back-gear usually reduces the speed of the spindle to one-sixth or one-tenth of that due to the cone-pulleys. The back-gear shaft is hollow, and turns upon an interior spindle which passes through it. At each end of this spindle an eccentric-pin is turned, which fits into bearings in

the head-casting. It will be seen that if the spindle be turned through 180° it will move the back-gear shaft bodily sidewise through a distance equal to twice the eccentricity. This distance need only be made a little more than the depth of the gear-teeth to furnish a most simple means of engaging and disengaging the shaft with its two gears. Some designers make the eccentricity larger, so as to require less angular motion of the back-gear lever to engage the wheels. The difficulty with this system is that the gear will throw itself out if the bearings are an easy fit. The strain of the gear is a lifting push, and if it takes the eccentrics at a favorable angle it will turn them. Most builders put the eccentric-pins so as to be on the line of centers when in gear. One maker turns the pins a little farther (Fig. 83), so that the strain which tends to separate the gear is opposed by the lower stop. Such an arrangement could not possibly throw out. The engaging-lever on large lathes is often doubled (Fig. 84). Some largest lathes, where the double-gear will be always in use except when polishing, have the composition boxes movable on their seats, so that they can be slipped sidewise, and are then held by a key.

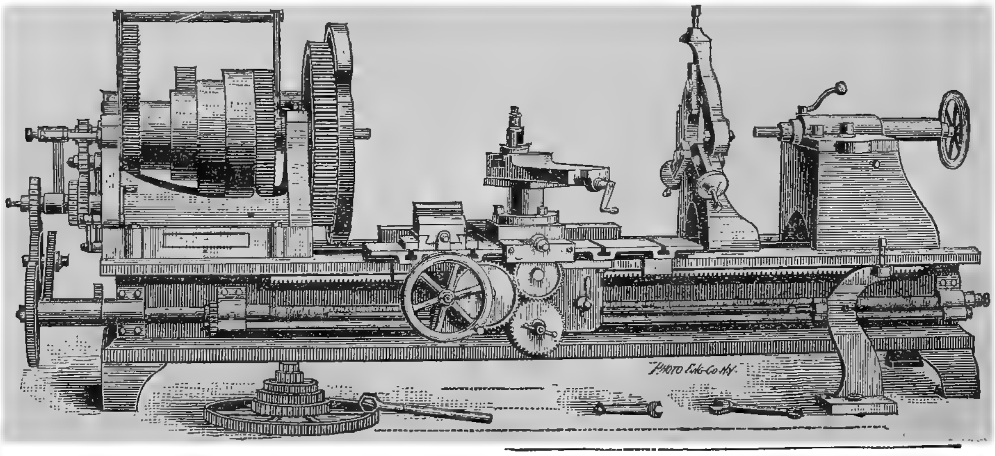


Fig. 84.

Many of the larger lathes are also triple-geared. Beside this back-gear combination, there are often teeth cut upon a circle larger in diameter than the gear which is fast to the spindle. These teeth will be upon the back of the face-plate, and will be driven from a smaller gear on the back-gear shaft prolonged, or else indirectly from it through idle gears (Fig. 85). In these large lathes the face-plate is never removed, since it is inconveniently heavy, and the work can very readily be driven by it. Where the face-plate is driven directly, it is necessary that both pinions on the back-gear shaft should be movable lengthwise on their splines, since they both must not be in gear at once with wheels of different diameters fast to the spindle. Where the power is transmitted through idle wheels, the slip-gear may be the one on the back-gear shaft only. It may slip out of gear with the spindle-wheel and into gear with the face-plate train, with an interval between their planes from which neither will be driven. Sometimes the whole back-gear shaft slides lengthwise and is held in place by a pin, taking into grooves cut in the shaft. The idle-wheel system is specially desirable where the face-plate teeth would come on its periphery. It is much better to make the face-plate teeth internal upon an annular flange in this case (Fig. 85), both for cleanliness, for safety, and to prevent interference with the chucking of large flat work. In many large lathes the cone-pulley spindle drives internal gear on the face-plate through an ordinary back-gear combination. The cone-pulleys are not on the live-spindle in this case (Fig. 86). Where the face-plate is larger than the gear-circle desired the teeth on the latter may be external. Some lathes for special classes of work are driven directly from a pinion on a splined shaft to teeth on the periphery of the face-plate.

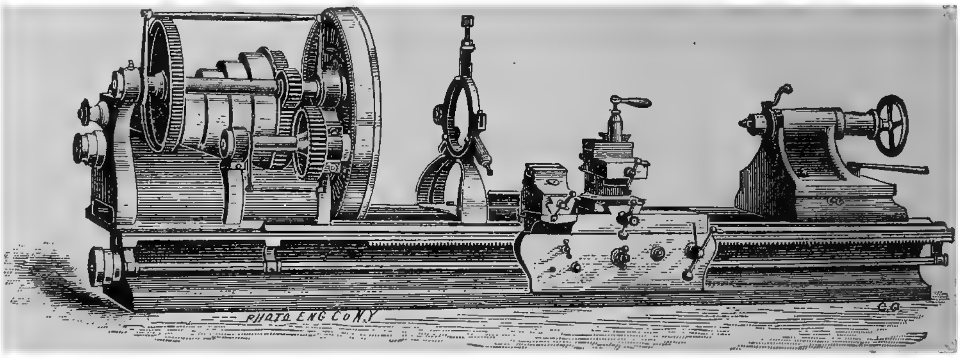


Fig. 85.

When the lathe is to be driven at speed for polishing or the like the back-gear shaft will be turned out and the cone-pulley will be clamped to the large gear fast to the spindle. This clamping is effected by a bolt passing through a slot in the plate of the fast gear-wheel. This bolt will cause a short slide to catch between jaws upon the inside of the cone-pulley, so that when the bolt is tightened the cone-pulley and gear become as one; or they may be clamped together by a regular friction device. For some special classes of manufacture, where the work, for example, is to be chucked, faced, polished, and drilled centrally, the back-gears and two speed-changes are all controlled by friction-clutches, so that the speeds may be changed without loss of time to stop the tool and shift belts or loosen nuts. One firm put several lathes upon the market in which the back-gear wheels were made with

helical teeth. The object of this was to cause more even working of the spindle and to lessen the vibrations of the work when driven through gears. It was not found to compensate for the trouble in shaping the teeth, and has been abandoned.

Upon the end of the spindle is secured the face-plate. This is simply a disk of cast iron, with radial slots in it, through which bolts and pillars can be passed to secure work to it. The front face of it must be a true plane and perpendicular to the axis of the lathe and of the spindle. It should also be balanced. It is usually screwed upon the end of the spindle, finding a true bearing at the end of the thread. As the lathe always turns in the direction opposite to that of the hands of a watch to one facing the inner end of the spindle, the resistance to the

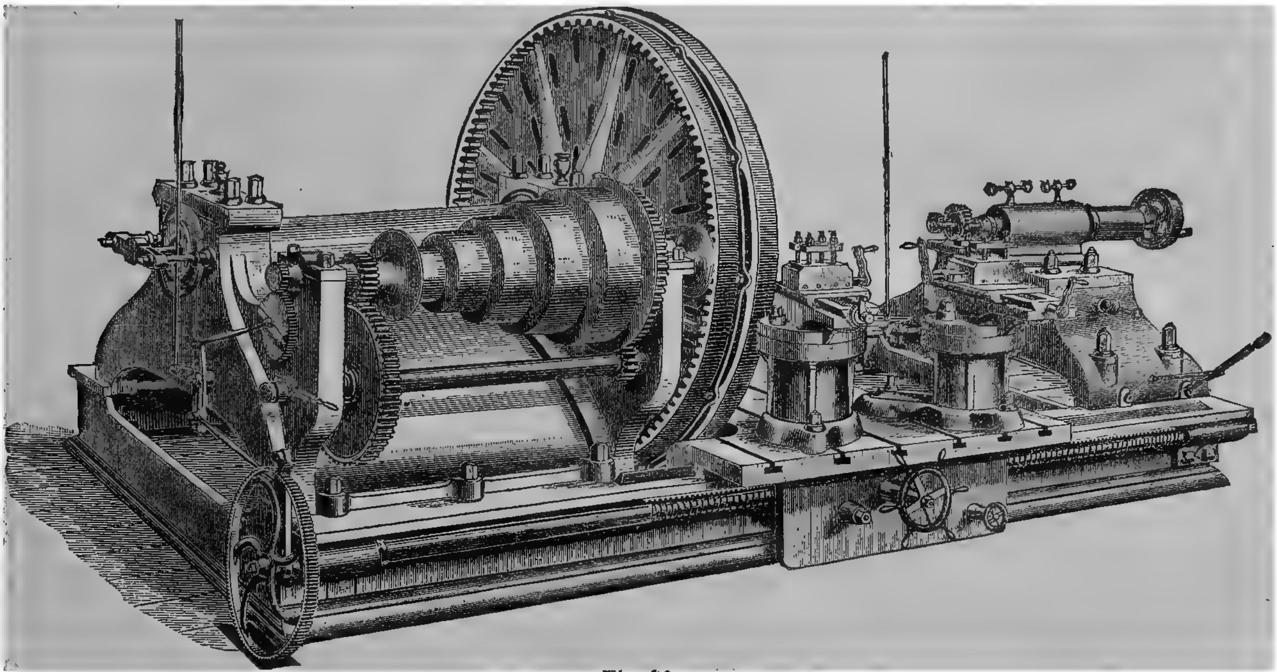


Fig. 86.

cut only screws the plate tighter when threaded on by a right-hand screw. Sometimes, besides the short slots, there are three or four long slots carrying jaws which can be moved upon the plate by screws in the slots. These serve to secure work to the plate, which will then be called a chuck-plate. For rod-work, screw-cutting, and the like, the face-plate is often replaced by a drive-plate, a flat disk with a slot cut on it along a radius to hold the tail of the dogs or drivers (Fig. 82). The four-armed spider is also used for dogged work (Fig. 83). A universal chuck can also be screwed on the end of the spindle when required. Usually the spindle is threaded to its end. In some cases the thread is made much shorter and the end of the spindle made to fit the plate or chucks upon a cylindrical surface left on it beyond the screw. This makes the adjustment of the plate more rapid and lessens the danger of battering the shears in cases where the heavy plate is only released from the screw when it is able to drop.

In the inner end of the spindle is bored the taper hole for the live-center. This, of course, must be truly central, and is made tapering to insure a tight fit at all times and truly in line. The taper is quite long, in order to secure ample bearing for the center when in place. The spindle is often made hollow in small lathes to accommodate lengths of rod, and also to permit the introduction of a rod through the tail-screw by which the center might be driven out when chucks were to be used. Where the centers were made of a long cone fit joined to the short cone center point by a short cylinder this device was very convenient. The newer centers are made with a squared surface outside the fit upon which a wrench can take hold to loosen them. The centers themselves are made of steel hardened at the point and ground truly conical in place. The angle of the cone varies from 60° to about 75°. The former is in many places more general. It is the apex of this cone which determines the axis of the tool, since all surfaces of revolution will turn around the line drawn between the points of the live- and the dead-center as an axis. It is necessary, therefore, not only that both cone centers should themselves be perfectly true, but that both apexes of the cones should remain in the intersection of the same horizontal and vertical planes in whatever part of the bed of the lathe the former may be.

It is the object of the tail-stock to insure the permanence of this axis of the lathe, and to permit considerable variations in its length. There will be a rough adjustment for length of work by hand, and a finer adjustment by a screw, while both must be clamped from moving out of adjustment when in place. The tail-stock is guided from lateral motion by the inner edges of a flat shear, or by the inner tracks of the V-shear.

When at the right position on the bed it is clamped in place by a cross-bearer, which is brought up against the under side of the bed. This clamp may be tightened by one screw from below, by an eccentric-cam, turned by a lever (Fig. 89), or by two or more bolts, one at each side of the casting. On the larger lathes there will be more than one clamp, and therefore more than one pair of clamping-bolts. The eccentric is adapted for medium and small sizes only. The screw arrangement is the most general. Upon the top of the movable stock is the finer screw adjustment for length. This consists of a spindle, cylindrical on small lathes and square upon some large ones, which has a long bearing (Fig. 87). This spindle may be moved in and out from the tail-stock by a screw which is turned by a hand-wheel or ball-handle from the extreme left end. This screw is usually cut with a left thread, so that the spindle may be protruded by an instinctive "screwing-in" motion. When the end of the center enters the drilled hole in the work, the spindle must be clamped to prevent the center from turning out. It is therefore necessary that the spindle shall move in the axis of the lathe independent of the tail-stock, and also the clamp must be such as not to throw the end of the center out of line. There are three types of clamps for the spindle. One form draws up a ring or forces a set-screw or other frictional device upon the center of the spindle from above (Fig. 88). The second clamps the outer end of the spindle by a screw which tightens a collar split upon one side. This collar is often a projecting part of the long bearing (Fig. 89). The third type (Figs. 90 and 87) uses a split sleeve tightened upon the spindle by a conical muff. The muff is drawn upon the sleeve by a screw when a partial turn is given to it. This latter system has the advantage that under abuse it will not be so likely to spring the spindle out of line, either up or down. The casing containing the long bearing for the spindle is cast solid. In the earlier forms, the cap which guides the screw had to be screwed on by a flange. The spindle is kept from turning by a spline.

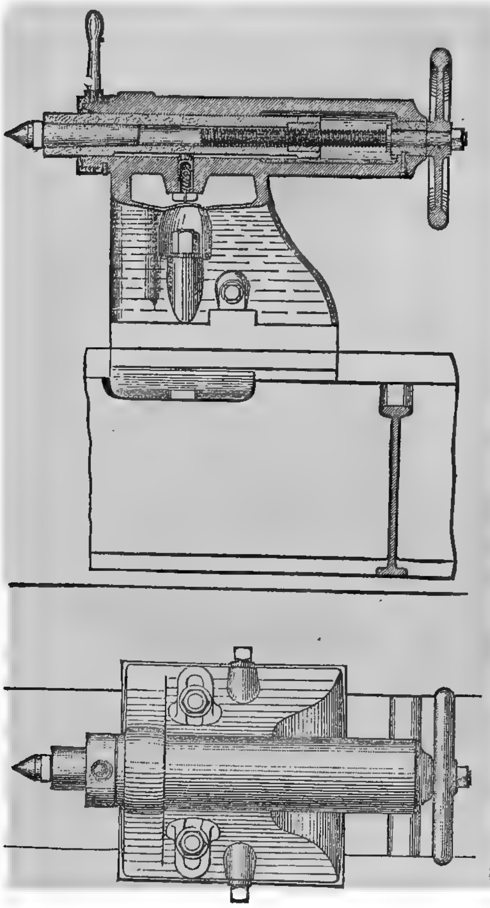


Fig. 87.

The tail-stock in universal practice is made in two parts. These are planed to fit together upon transverse ways, and secured by clamping-bolts or by set-screws.

The object of this arrangement is two-fold. It is desirable to have this lateral adjustment of the dead-center, because in boring the casing for the spindle in the first instance it is hard to get the lateral accuracy of the boring-bar relative to the shear-guides. The vertical adjustment is easy. Since it is desirable to have a little lateral adjustment for the dead-center when in place on the shears, this lateral motion can be easily made larger, and the lathe will then turn conical surfaces as well as cylindrical. Such tail-stocks are called "set-over tail-stocks", and have been hitherto almost universal. Advanced practice of to-day, however, prefers the use of an attachment for turning tapers which controls the motion of the tool. This system not only avoids the difficulty of readjusting the rear spindle after every taper, but also permits the boring of taper holes without a compound rest. When taper attachments are used, the tail-stock has only sufficient motion for adjustment. The older standard form of tail-stock is shown by Fig. 91; the newer shape is that of Fig. 81.

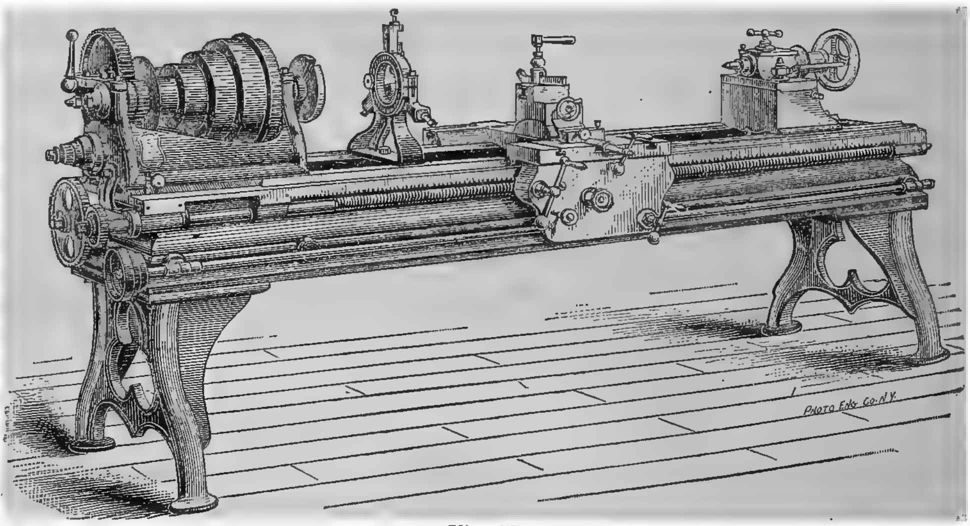


Fig. 88.

Very often a small oil-cup is cast in the spindle-casing, from which the lubricant can very easily be put upon the stationary center. The largest tail-stocks are too heavy to be moved directly by hand, so that a small pinion is made to engage in a rack at the side of the bed, and the squared end of its vertical axis will take the end of a long lever. The rotation of the pinion drags the heavy casting upon the shears. On some of the largest lathes also the tail-spindle has power-feed for boring. This type will be illustrated by Fig. 92 and further in advance.

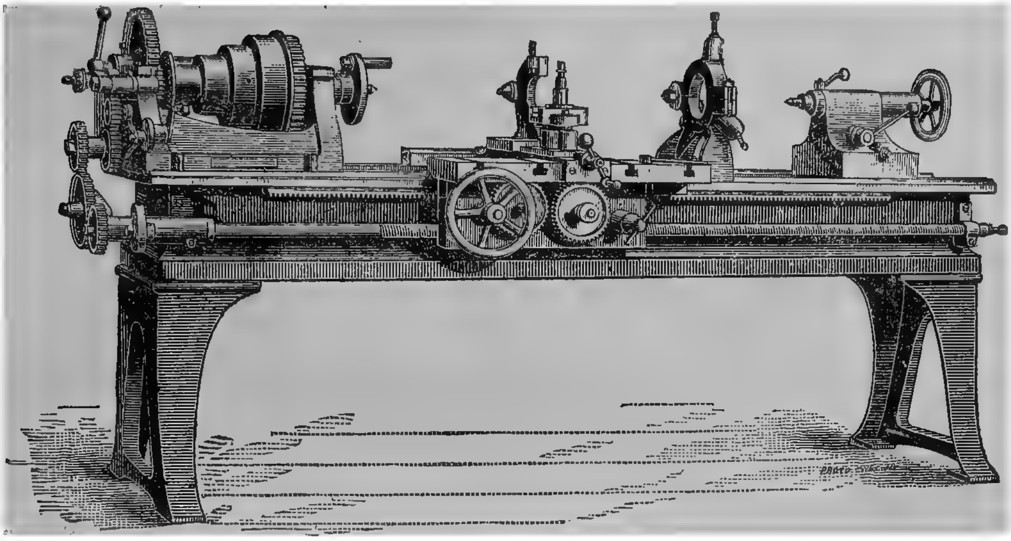


Fig. 89.

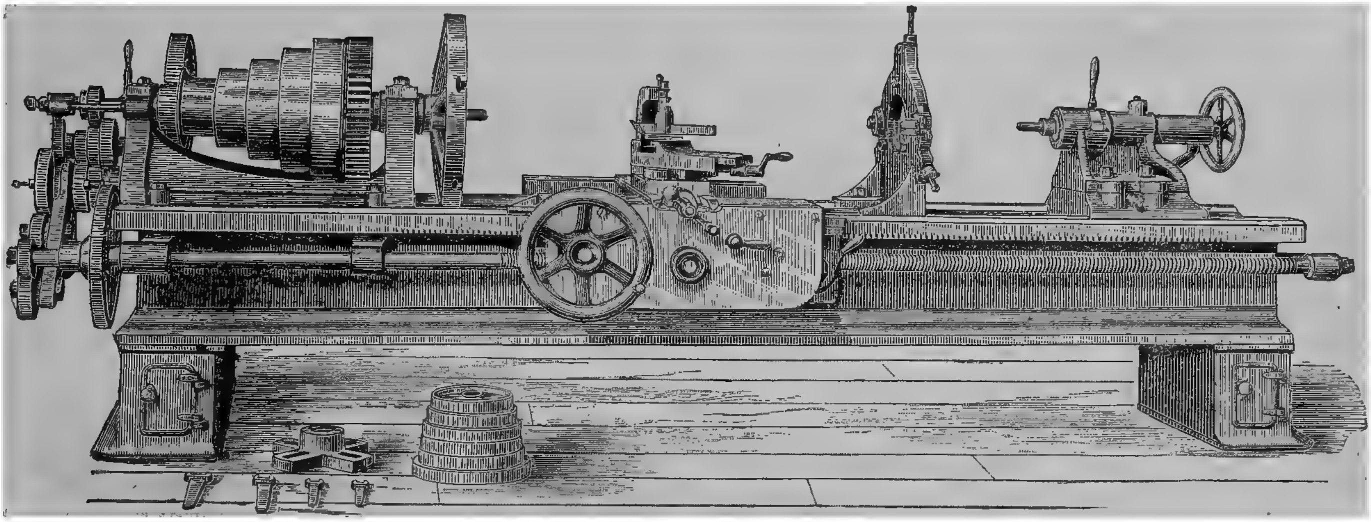


Fig. 90.

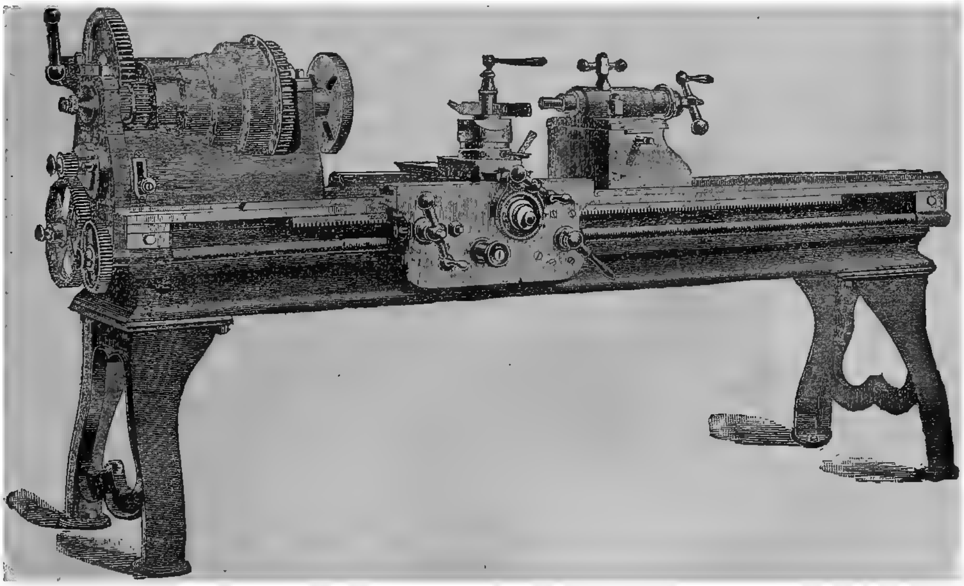


Fig. 91.

The line between the centers being thus made exactly true, it remains to give to the tool-point a motion which shall be truly parallel to that axis, and also one at true right angles to that axis. The motion of the tool parallel to the line of centers must also always be in the same plane with that line. The tool will therefore be rigidly held in a

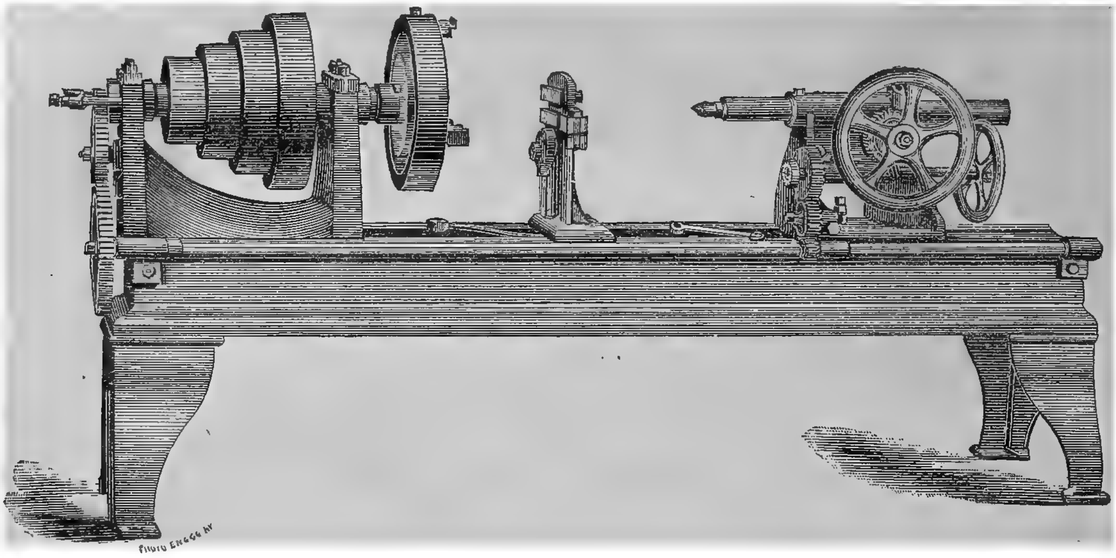


Fig. 92.

tool-post, supported upon a guided carriage. This carriage must receive the two motions at right angles to each other, each motion being independent of the other. The lower part of the carriage will span the opening between the two sides of the bed, so as to be guided by its extreme ends. In the flat shears the tendency to twist the carriage is resisted by the outer surfaces of the shears. These incline inward, and adjustable gibs are fitted against these inclines front and rear, which also keep the rear end of the carriage from lifting under the strain of the cut. In the V shear system the carriage rests upon the outer rail of each shear, and is thus kept from lateral motion. Flat gibs under the square edges of the shears resist what little tendency there may be to cause the saddle to lift. In both cases the bearing surfaces of the carriage are made much longer than is necessary, simply to support the cross-rail or saddle. The plan of the whole would be usually a square, in which the sides were broken away to enable the saddle to come close to the head- and tail-stock. The necessity for these long guiding wings to the carriage results from the method of driving the carriage from the extreme of one side, and also from the leverage exerted upon the tool-point in certain positions. It is an argument urged against the V-shear system that the long span of the saddle to clear the inner rail makes a greater thickness of metal necessary at that part for stiffness, and therefore reduces the swing of the lathe. The shortest radius from the center to the shear limits the face-plate work which the lathe will take in. In long work the limit is fixed by the shortest distance from the axis to the saddle, and the thinner this is the greater the swing of the lathe. This difficulty is met by thickening the metal of the saddle downward between the shears. Nearer the abutments the depth may be reduced. The majority of the carriages are what are called half-gibbed. The gibs take hold below the outer back and the inner front of the shears. Flat-shear and many V-shear carriages are gibbed at the outside, back and front. There are comparatively few which are gibbed on all four surfaces.

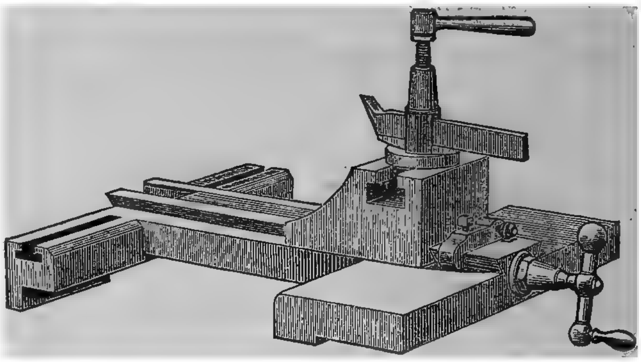


Fig. 93.

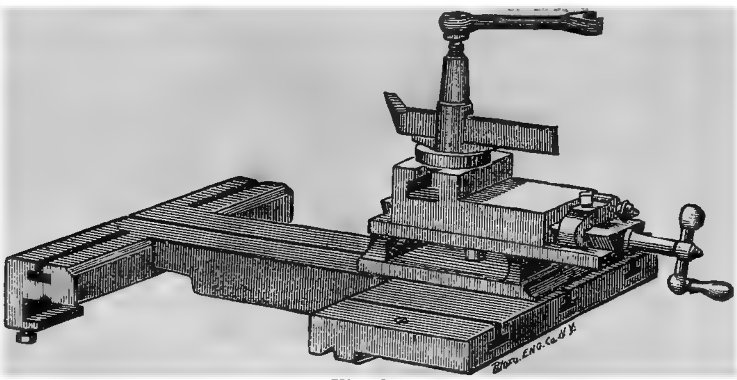


Fig. 94.

Fig. 93 shows the ordinary plain gibbed rest for small and average lathes. The apron which holds the driving gear, to move the rest automatically, is secured to the flat surface at the under side of the front. The cut shows the ordinary tool-post, consisting of a block with a T-socket in its top. The post is slotted out so that the shank

of the tool may pass through it, and a set-screw in the axis of the post screws down upon the tool. The abutment is the round head which fits into the T-slot and binds tool and post to the block. For the adjustment of the point of the tool, that it may come opposite the horizontal diameter of the work, is the object of the washer below the tool. This is dished out into a segment of a hollow sphere, and a steel segment of a zone of the same sphere fits into the hollow. The tool rests upon the flat surface of the wedge, whose spherical lower side permits the tool to have a full bearing at any vertical angle within the necessary limits. The same object may be attained by a spiral washer under the tool.

It is the block below the tool-post which receives the cross motion at right angles to the axis of the lathe. Upon the saddle are planed flat, dovetail shears, truly at right angles to those of the carriage below. The post and block can be moved on its shears by the cross-feed screw which holds against the carriage between a shoulder and the ball-handle spacer-washers. The tool-block is made with long bearing surfaces, and any wear in its fit is taken up by screws which bear upon an adjustable gib. The T-slots on the rear wings are planed out to receive a back-rest or any other convenient attachment. On larger lathes, what is known as the "Philadelphia rest" is often used (Fig. 94). An open casting slides in a T-slot across the carriage, to which it can be bolted. The shears for the tool-block are on the top of this adjustable foot. The advantage of this form is that it can be bolted to any part of the rest by the T-slots wherever the exigencies of the work may demand, or the whole tool-holder can be removed, so that the flat carriage only may be left. The cross motion, however, cannot be automatic.

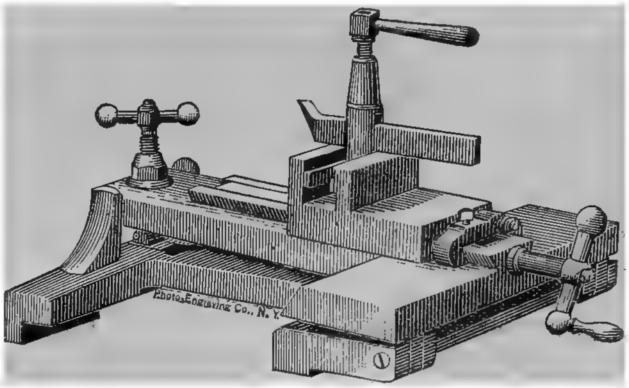


Fig. 95.

For many classes of light job-work the easy, rapid, and secure adjustment of the point of the tool is of considerable moment. To effect this is the object of the gibbed rest shown in Fig. 95. The saddle is made double, the top half revolving around a horizontal hinge at the front. The lifting-saddle is prevented from twisting strain

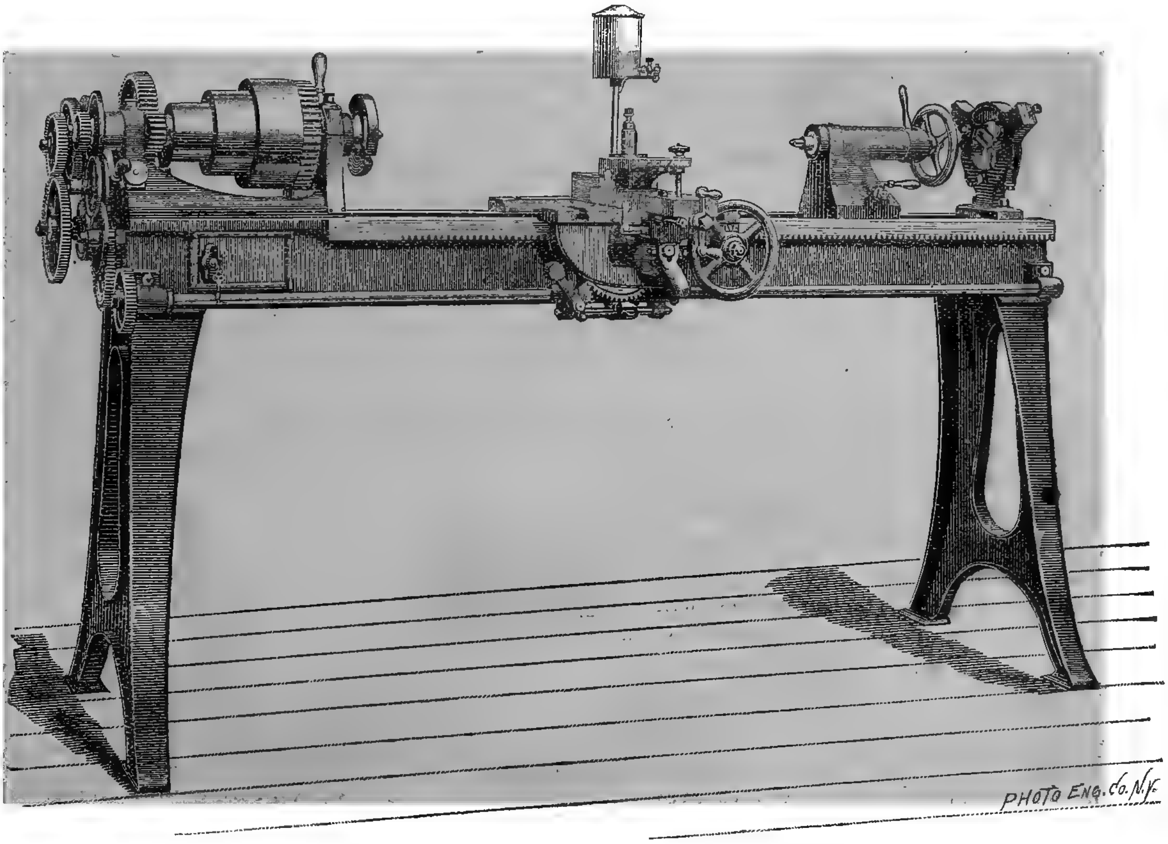


Fig. 96.

by the faced brackets at the back, and the degree of elevation of the rear end is controllable by a screw, which passes down into the lower saddle. The motion of the screw in the upper and lower saddle is circular around horizontal axes (Fig. 96). This is provided for, and lost motion is taken up by several devices. The most usual

is to make the lower end of the screw spherical, which fits between brass washers, curved to fit the ball. These washers are confined by a screw-sleeve in the top of the lower saddle, by which any play can be taken up. In the upper saddle the nut for the screw is also made externally spherical and confined by similar sleeves. Others pin the end of the lifting-screw into a slide on the lower saddle, so as to avoid the ball-and-socket fit. Wear is taken up in the nut by splitting it across the axis, and controlling the approach of the two parts either by the sleeve-nuts or by conical-pointed set-screws. In rests of this type the tool-block slot is so made as to give a stiff hold for the tool at a distance from the set-screw. Not infrequently the top of the block is serrated to increase the friction.

Other methods of raising and lowering the tool-point are shown by Figs. 88 and 91. In Fig. 88 the gibbed block slides over a shear on the surface of a horizontal cylinder. A rack on the end of a screw meshes into a sector on this cylinder, and the point of the tool rises in an arc. Another device has the cylindrical surface replaced by a spherical surface, the head of the slotted bolt coinciding with the center of the sphere. This works very well as long as there are no defects in the spherical contact. Still another uses inclined planes on the two halves of the post, controllable by a separate screw. The disadvantage of these methods is that horizontal adjustment of the block must be made after every vertical change. A joint where lost motion may occur is also introduced between the tool and the carriage. Another plan, which has the advantage of stiffness, makes the post with a screw-thread on its lower part. By raising and lowering this large pillar-screw the point rises and falls. One similar design raises the tool by a capstan-nut on the outside of the post, while internal to the post is another which acts to clamp the whole from moving. In still another the pillar of the post is lifted by an elbow-joint, clamped by the screw which controls the joint.

For small lathes an especial practice prevails in New England. The slide-rest carriage, moving on V-shears, is kept to its bearing on the track by a weight, and no gibs are employed. This system gives great steadiness of motion for light cuts, since all lost motion of adjustment and for free travel is absorbed in the weight. The hinged saddle is used, lifted by the end screw by contact joint only, and no "take-up" devices are required (Fig. 97). The cross-feed can be only limited in length on this system. When wide surfaces are to be faced, the post-block must be reset in the slot. No tools of this design are approved at the South or West, but in New England they are preferred by many of the best workmen and builders. As the swing of the lathe increases the height of the tool-post must increase also. To increase the capacity of the tool-holder, the compound rest is approved. The lower block, which may travel across the bed at right angles to the axis of the lathe, carries a horizontal flat disk with a circular T- slot in it. Upon this disk may be bolted at any angle a secondary tool-post, which has a screw cross-feed motion upon its own shears (Fig. 98). So that, beside the two motions at right angles to each other, which are common to the smaller devices and are here retained, the tool may have an angular feed in any direction for turning tapers and conical shapes. On lathes of the largest size, where the pillar on which the tool-holder stands is quite high and the cuts will probably be heavy, the form shown in Figs. 99 or 100 is used. The tool is held by two clampings-crews, and while the large post has the two original motions, the holder on the top has also two motions at right angles for convenient use by hand. In newer practice, even these feeds can be driven by power for smaller work.

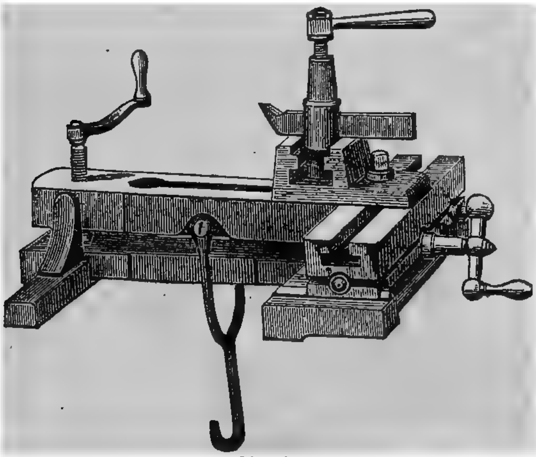


Fig. 97.

To actuate these carriages automatically by the power of the tool itself two general systems are in use. One moves the carriage by a screw, whose nut is held in the apron of the carriage, and the other by a driven pinion in the apron, which meshes into a rack on the under side of the shear. Both systems may be combined in one lathe for different uses. The screw-feed will be used for the reproduction of screws; the feed by the pinion, usually known as the "friction-feed", will be used for the general turning in the lathe. The driving-screw is continuous for the whole length of the bed. It is often called the "lead-screw" or the "feed-screw". In very long lathes it has to be supported to prevent sagging between supports. This is accomplished by flat hooks, which catch hold of the shears and pass under the screw. They are perfectly movable and can be put where most needed. Usually they bear on the tops of the thread of the screw. The thread may be cut away for a length less than that of the nut in the apron if it is desired to give the supporting hooks a complete straight bearing. The lead-screw may be put in front of the bed, at the back of the bed or between the shears.

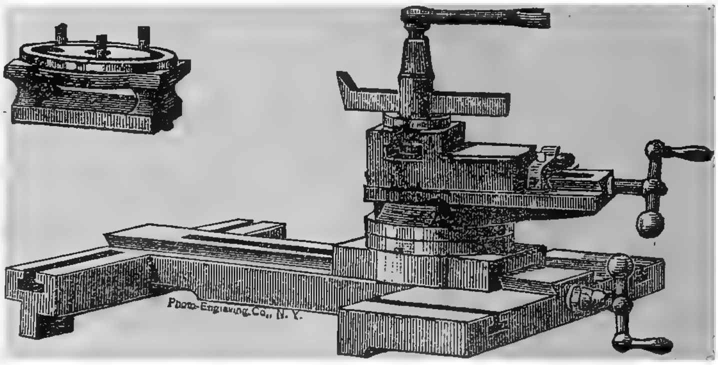


Fig. 98.

There is but one designer using this latter system. In this make, the screw is supported in a trough in the shear casting, and is protected from chips by the projection of the shear. A half-nut or chasing-nut is used on the carriage. The preponderance of practice has the screw in front of the bed. The friction-feed apparatus is always in front.

The screw is driven by a train of gear-wheels from the spindle of the lathe. These wheels come in sets, so

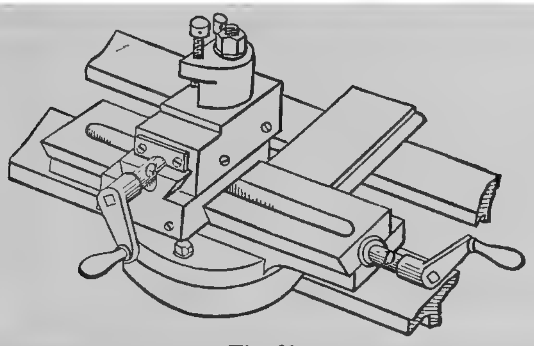


Fig. 99.

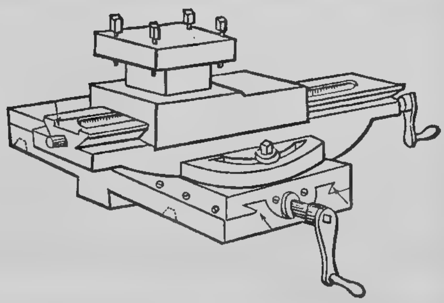


Fig. 100.

that almost any esired combination may be interposed between the spindle and the screw, to vary their relative velocities. If the spindle and the screw turn at the same rate, the tool-point will cut a duplicate of the lead-screw on the work, since each will have gone round the same number of times while the tool moved over one inch. To cut any other thread the revolutions or the number of teeth on the wheels of the first and last of the train must be as the thread to be cut is to the thread of the feed-screw. It is therefore convenient that the pitch of the feed-screw be a convenient divisor of the usual threads. Very often it has four threads to the inch. One designer uses two threads to the inch, for convenience of calculation and to make it more easy to strike into the thread under the cut. To connect these fixed studs at the two ends of the train the studs upon which the intermediate idle wheels are placed are borne upon a slotted swinging casting, which revolves around the screw or its journal as a center. The studs for the wheels take into these slots, and the casting is clamped by a set-screw to the head of the lathe (Fig. 101).

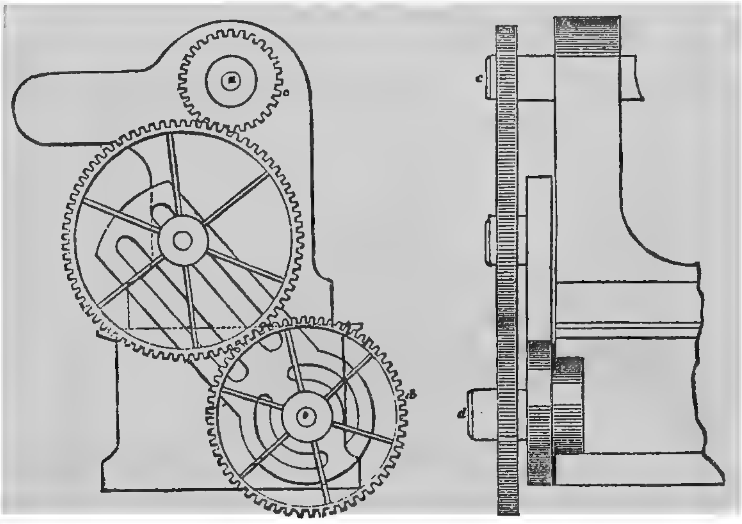


Fig. 101.

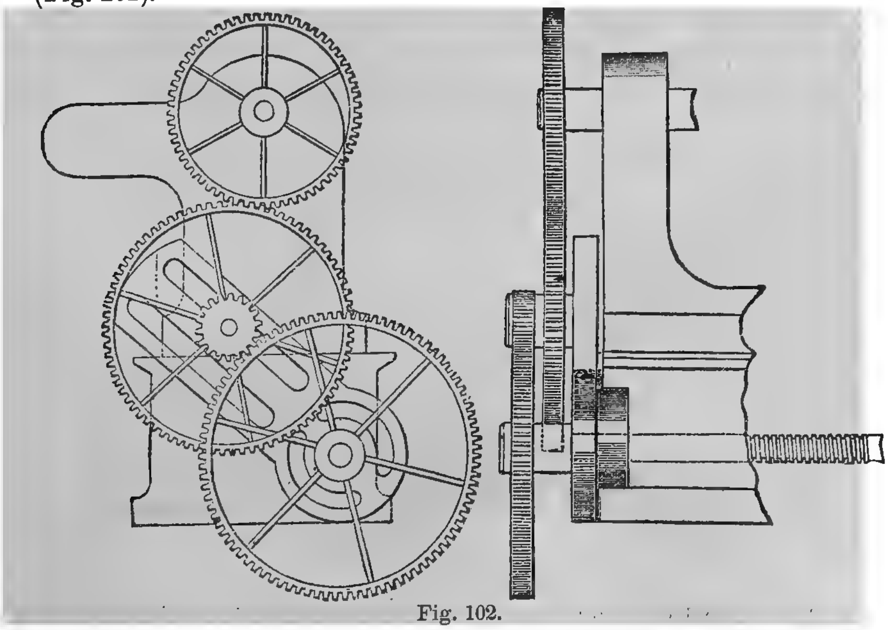


Fig. 102.

Many lathes of large swing having a large feed-screw with small number of threads to the inch will be double-geared or compound-geared. By this is meant that upon one idle shaft are two gears of different diameters turning together. A larger range of speed between the spindle and screw is obtainable with few gears. To avoid confusing the operator with different motions for reversing it is best always to have the same number of spindles in the train. Also, the use of a large gear on the screw may be avoided, necessitating a cut in the floor, and heavy gears are dispensed with. There may be also the gain due to the greater smoothness of working when the driver and follower-gears are more nearly of the same size than would be possible with the single gear. The arrangement is shown by Fig. 102. The tendency is toward smaller diametral pitch in the change-wheels. While it used to be 12 per inch, it is now 6, and some prefer 4 per inch.

For reversing the motion of the screw in general practice one method is preferred. It depends on the principle that in any train of external gears the even numbers in the series will be turning in one direction and the odd numbers turn in the other. By a simple motion of a lever the train of gears driving the screw may be made to contain an odd or an even number of wheels. In Fig. 103 a V-shaped lever turns at its apex on the stud of one wheel as a center. On one arm of the V is one wheel and on the other are two. If the V is rotated so as to bring the driving-pinion D into gear with one arm, the follower at the apex will turn one way; if with the other arm, the follower will turn the other way. There is, of course, a neutral position, in which the driving-pinion will drive neither. The lever which moves the V projects conveniently for the hand of the operator, and is prevented from disengaging itself either by a latch-pin into holes, or by a clamp-screw, or by a little cam. The clamp-screw requires the use of both hands.

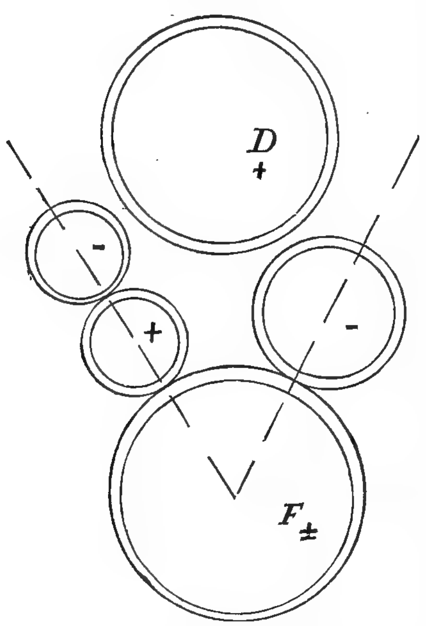


Fig. 103.

Another type of reversing mechanism uses the principle of the two loose bevel-gears driven by the third between them. The combination is put under the cone-pulleys, and a clutch is engaged by a rod from the apron with one or the other of the loose gears. The advantage of engaging and reversing at the head also rather than at the carriage only is that, when speeding the lathe for polishing, the gears need not be clattering and wearing each other out. For engaging and disengaging at the carriage, the universal device is a split nut. This is divided along a plane through the axis into two parts, which approach to clasp the screw or recede to release it at the will of the operator. This clasp-nut has the halves moving in guides so as truly to come together and make a nut, the motion to open and close being given to both parts. Usually this motion is given by a disk in which are two spiral slots. In these slots fit two pins, of which one belongs to each half of the nut. The slots are so laid out that when a partial rotation is given to the disk the pins come equally toward its center or recede from it, carrying the sliding halves of the nut. Another device draws the halves together by fitting them to a bolt with a right thread on one half and a left thread on the other.

This clasp-nut device is practically universal in lathes driven from the screw in the apron. A New England design, with the screw at the back, uses a solid nut, which bolts through a bracket to the saddle by easy working tap-screws, when required. This system of solid nut renders obligatory the use of reversing counter-shafts—a system expedient in all cases for the economy of time and exactness of screw profile. Left threads are cut in this single-connection system by putting an extra idle-wheel in the gear-train.

The use of the screw and nut for ordinary turning-feeds has two objections. The principal one is the wear of the screw, which will be greatest near the head-stock where the greatest amount of work will be done. Therefore a long screw cut on such a lathe will not be uniform or regular. The nut will also wear and permit lost motion. A second minor objection is that the ordinary feeds are so much slower than a screw-cutting feed that considerable rearrangement of the train is necessary to get the proper speeds when the work varies. To avoid these difficulties, nearly all the smaller and medium lathes of to-day are provided with a second feed system, known usually as the "friction-feed". Motion is imparted to a train of gears in the apron of the rest, by which a small pinion is made to turn in gear with a stationary rack upon the shear. This train of gears is engaged and disengaged by a friction-clutch in the apron.

Figs. 104 and 105 show a plan and elevation of a very usual form of the gears in the apron. The rod *f* is driven by a narrow belt from a cone-pulley on the first spindle of the change-wheel train. There are usually three changes

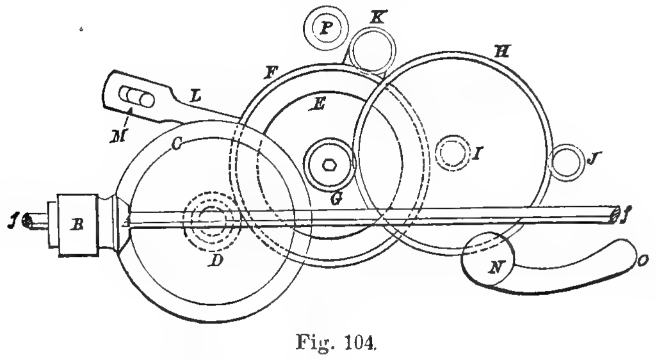


Fig. 104.

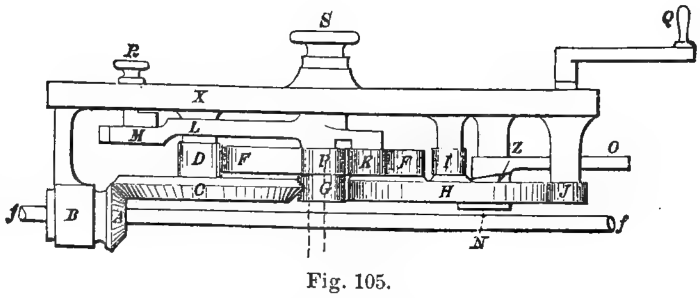


Fig. 105.

on the cone, and the reversing is done either by the lever with the one and two gears, or by crossing the little belt, or it may be done in the apron. This rod is splined, and carries a bevel-wheel, A, mounted on a bracket, B, from the apron. The rotation of *f* will therefore turn A wherever the latter may be upon the rod. When A revolves,

it turns the wheel F, which is the female part of a friction-cone. The rest of the train, up to the rack, is connected with the male part of the cone (Fig. 105) through the pinion G. The cone is engaged by the screw Y, controlled from outside by the hand-nut S. The wheel H catches in the rack under the shear, and on the axis of the pinion J is put the ball-crank or hand-wheel for traversing the carriage by hand. It will be seen that if a second bevel-pinion be put opposite to A, so that either may be at will engaged with C, a very simple reversing and disengaging gear is designed, which is worked from the carriage entirely, without stepping to the head. In many designs the bevel-gear A is replaced by a worm. This permits the reduction of speed to be made with few wheels in the train. For reversing in the apron, one designer has one right and one left worm on the rod, either of which can be brought under the worm-wheel by a lever in front.

The worm-system is objected to by many builders on account of the danger to it if allowed to get dry by neglect. The wear of the surfaces becomes very rapid. The wheel is made of cast iron, the worm of wrought iron, steel, or cast iron. In some cases it turns in an oil-pan to keep it lubricated. Very often, instead of driving the wheels in the apron from a separate splined rod, the feed-screw is splined to carry the worm on the bevel-gear. This is objected to by some on the ground of the wear on the top of the thread and at the points of the threads where they are cut by the spline. One designer gears the rod to the screw and drives both at once (Fig. 89). The end play of the screw is prevented by a steel step-screw or by a washer of some material like rawhide. When a lathe has both feeds in the apron there have been devices to prevent the operator from throwing in both at once. For reasons of simplicity of mechanism this attachment is not often applied. The gears are usually carried on studs bolted into the apron. To avoid the strains on the overhanging bearings one designer makes the apron with two walls (Fig. 81). Another plan has all the gearing on the outside in front (Fig. 89); this is a gain in cleanliness, but there is more danger of accident to a careless operator. The rod-feed of the lathe shown in Fig. 80 is driven by a friction device by means of which the speed of feed may be varied. A smooth disk of cast iron is the driver, which is clasped by two disks of brass upon its sides. These disks of brass are kept against the iron by a stiff steel spiral spring. A second disk of cast iron upon the splined rod is driven by the contact of the brass plates on the side of their axis opposite to that of the driver. The axis of the connecting plates is movable along the line of centers of the driver and follower disks, so that any ratio of radii within the limits of the design can be secured. In this lathe also the screw is not clamped between the two halves of a nut, but a half-nut presses against the screw laterally, and flexure is prevented by the shape of the shear casting. In the Sellers small lathe the rod-feed is often driven by their frequent device of a concealed worm or spiral pinion. In the Miles lathe the feed is driven by an original device to avoid the loss of time in changing the gear-train (Fig. 106). The live-spindle is

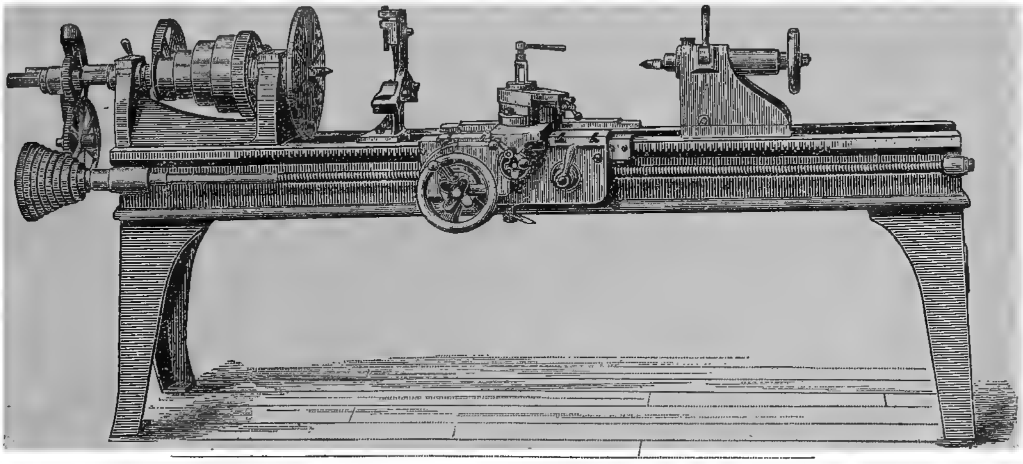


Fig. 106.

prolonged for some distance at the head of the lathe, and is splined to carry a spur-wheel and pinion. At the rear of this spindle is a round horizontal pillar, upon which slides an arm, carrying an idle wheel on a horizontal stud which can connect either spur-wheel or pinion to a nest of gear-wheels of different diameters fast on the screw. The pillar is graduated so that the edge of the arm may be rightly clamped to cause the proper thread to be cut. Changes of feed speed by this arrangement are very simple and rapid and the gear is durable. The racks under the shears are usually in segments, screwed in place. They are of wrought iron, steel, or cast iron. Steel is preferred by some because of the weakness of the teeth of fine racks under strain of the feed.

The screw for the cross-feed of the tool-post is most frequently engaged by a second friction-clutch operated like the other by a screw (Fig. 78). This takes hold of the gear before the other, so that both may be used at once or only the one which is required.

The arrangement shown in Fig. 104 is a type of another system where the connection is made by moving an idle pinion into the train. The pinion K is on a stud upon an arm which turns around the axis of the driving cone-

wheel F. A slight motion of the arm around its center will put the idle pinion into gear with the pinion on the cross-screw P. This can only be reversed by reversing the motion of the rod. For large wheel-turning lathes and the like, the cross-feed has often been driven by a click and ratchet motion by a weighted lever (Fig. 107). A

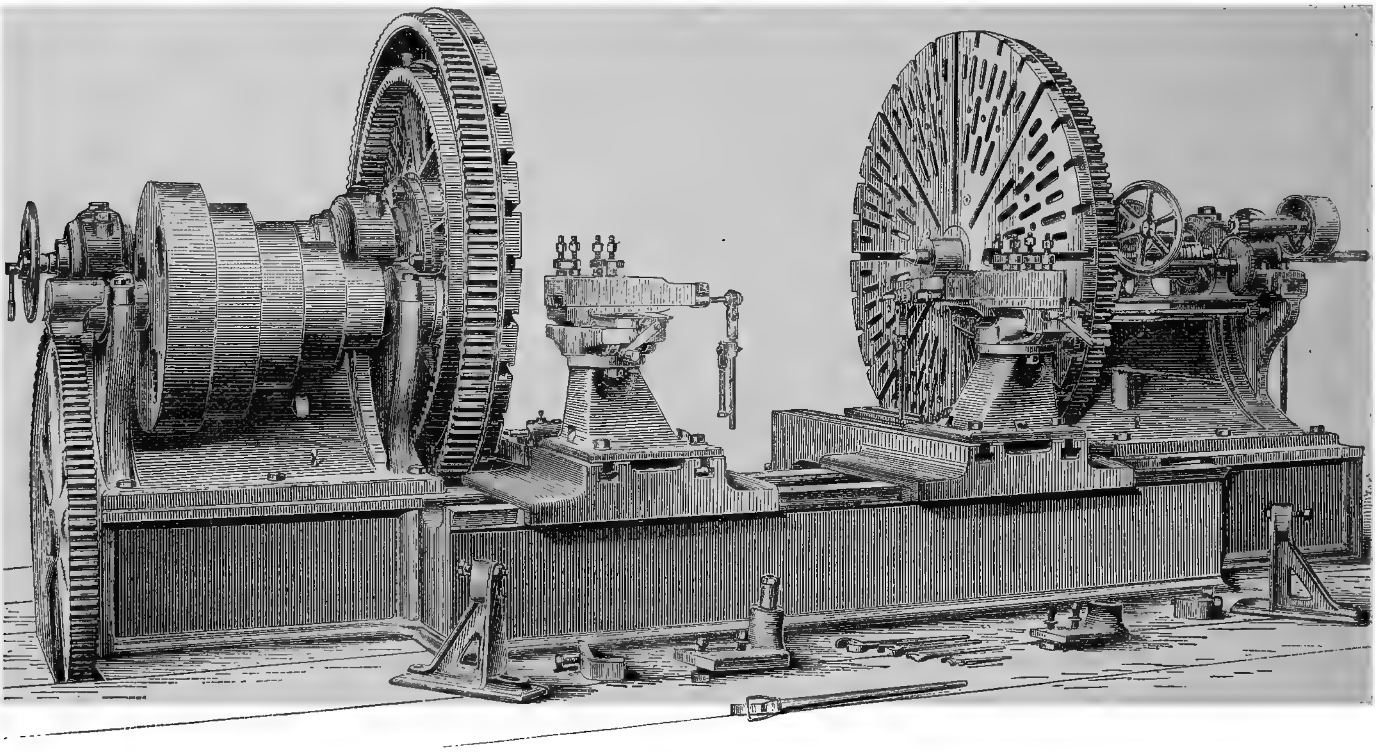


Fig. 107.

rope passes from an adjustable crank at the head-stock to a pivoted lever overhead, and from thence a second rope comes down to the ratchet lever on the screw. The intermittence of the motion is compensated for in the spring of the tool. A longitudinal ratchet-feed is not now used to any extent (Fig. 86). The saddle may be clamped against longitudinal motion when cross-feeding by a movable gib, or by any convenient device.

To avoid the inconvenience that the friction-cones in the apron will sometimes set themselves, a designer in Philadelphia makes the clutch cylindrical, of a split steel ring, kept open by a little cam. When the cam is turned the ring closes and engages the gear. There are several devices in use to prevent the unintentional seizure of the conical forms.

Every lathe has certain accessory appliances as part of its furniture. One of these is called the "steady-rest". It is intended to support long cylindrical work which might sag by its own weight between centers. It consists of a frame to support three radial sliding jaws which can be moved toward the axis of the tool by screws. The rest

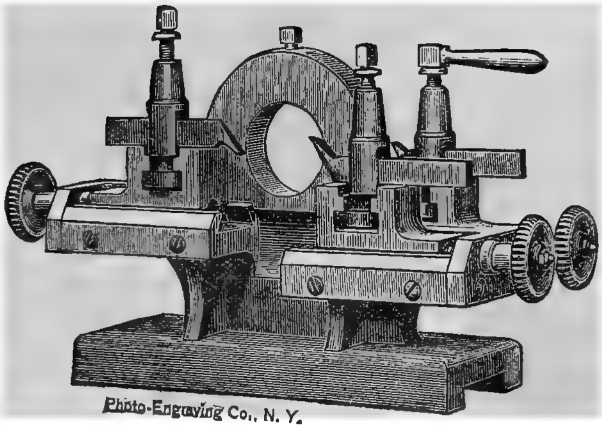


Fig. 108.

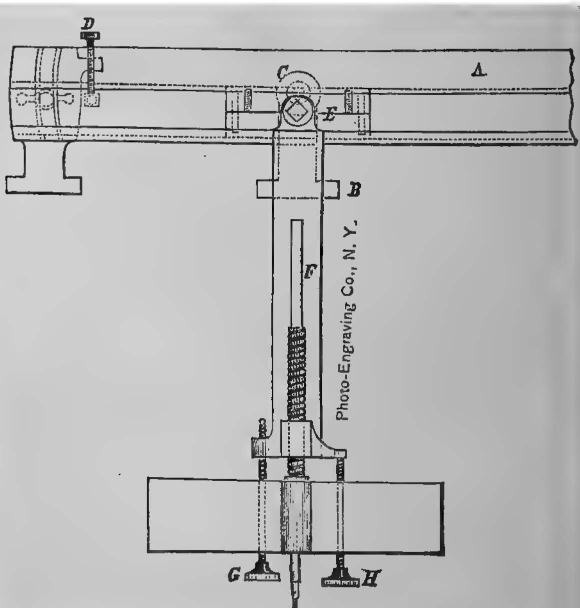


Fig. 109.

stands on the shears and is clamped by a cross-piece below. The cylindrical frame which holds the jaws is split at the horizontal diameter for convenience of inserting and removing work, two of the jaws lying at angles of 30° below the horizontal line. When the work is not cylindrical, a shell "doctor" with radial set-screws in pairs can be secured to the work so as to turn centrally upon the jaws of the rest. To resist the horizontal spring of light work away from the tool-point, a "back-rest" is used. A curved upright bolts in T-slots in the carriage, and adjustable jaws oppose the pressure of the tool. These difficulties are overcome in lathes for turning shafting by making the rest on the duplex system (Fig. 108). There are two tools opposite each other, one turned up and one turned down. A third tool may produce the finishing cut, and the shaft may be sized perfectly by a hollow reamer.

A type of the attachments for turning tapers on a lathe is shown in plan in Fig. 109, and in place on the lathe in Fig. 110. At the back of the bed are three brackets which carry a grooved bar. This bar can be adjusted

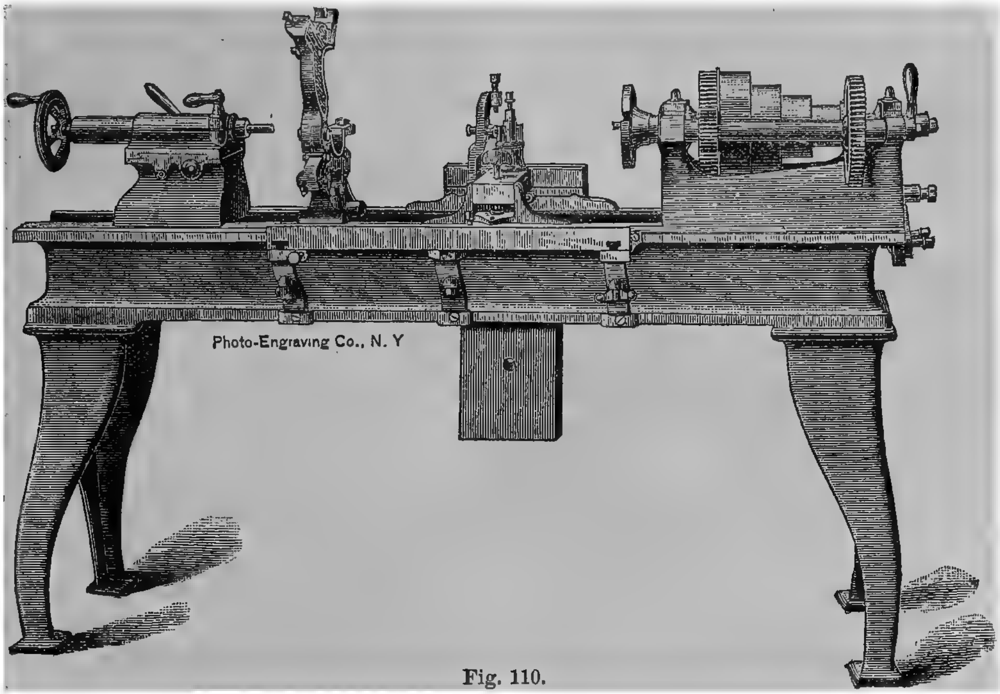


Fig. 110.

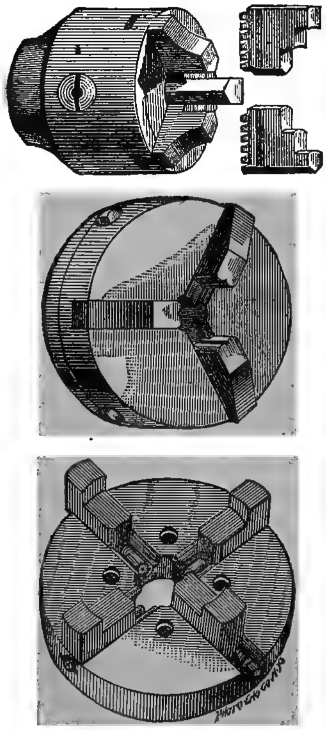


Fig. 111 *a*.

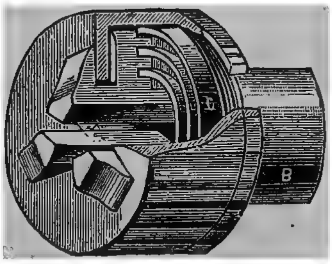


Fig. 111 *b*.

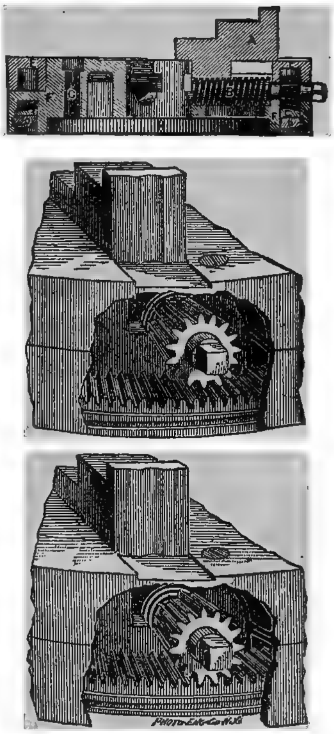


Fig. 112.

parallel to the axis of the tool or at any angle with its horizontal projection. In this groove slides a block, E, which is pinned to the nut-bar F, which slides in a groove in the lower part of the tool-carriage. G and H are stop-screws to be used in outside and inside work respectively. When the bar A is swung around its center pin, C, and clamped into the required position as determined by the tangent-screw D, a gradual transverse motion is imparted to the upper part of the tool-carriage in and out from the centers. This type of attachment is unaffected by the length of the piece, requires no preliminary cuts for trial of the taper, works as well for inside work as for outside, and avoids setting the centers out of line. A similar type which avoids any lost motion of the slide in the groove holds the guiding surfaces in contact by a weight over a pulley.

A universal or self-centering chuck is a usual accessory. These are made for small and medium lathes upon two principles. The jaws are usually three or four in number, sliding in radial grooves. The scroll-chucks have a plate with a continuous flat spiral groove cut in it. The jaws have projecting lips, which enter the groove, and when the scroll-plate is turned the jaws all move equally toward the center (Fig. 111 *b*).

The second type has the jaws mounted and moved inward by screws. These screws have each a small pinion near the outer end meshing into a large gear concentric with the chuck. When one of the screws is turned the others must all turn equally and the jaws will move to the center. Fig. 111 *b* shows a type of scroll-chuck. Fig. 112 is a screw-chuck of the second type. The screw type enables the lost motion due to wear to be taken up. Each screw can be separately tightened by the wrench in this form, since the two gears may be disengaged. The special chucks, the drill-chucks, and the eccentric-chuck, the mandrels, and the dogs and drivers, are articles of especial purchase or manufacture.

§ 17.

SPECIAL FORMS OF LATHE.

Special constructions of lathes are adapted for special uses. Where a large chucking capacity may be called for, but only average swing over the rest of the bed, a gap-lathe (Fig. 113) may be used. This gap may be permanent, or the shears may be in two tiers, the upper or working bed sliding over the gap when it is not needed. Where work is always to be of large diameter and flat, of such a shape as to be worked best on the face-plate, the bed may be made short and the tail-stock may be omitted. This form of lathe will be called a chucking-lathe (Fig. 114). For very large fly-wheels and work of that class a chucking-lathe only is required, and very often the face-plate and tool-carriage rest upon separate foundations, and are really separate machines.

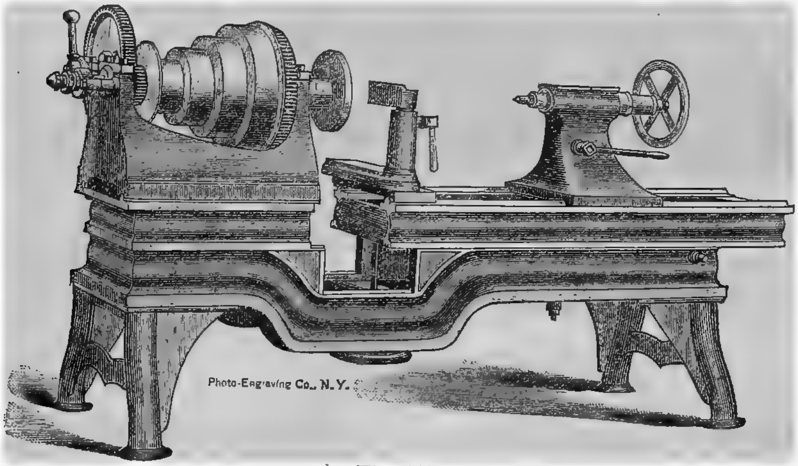


Fig. 113.

A lathe especially adapted for locomotive driving-wheels is shown by Fig. 115. There are two large face-plates driven from pinions on splined shafts. This avoids the twisting strain on the axle when the resistance comes at the end of a long lever. The frames of the heads are of the box pattern, giving great stiffness. There are two tool-

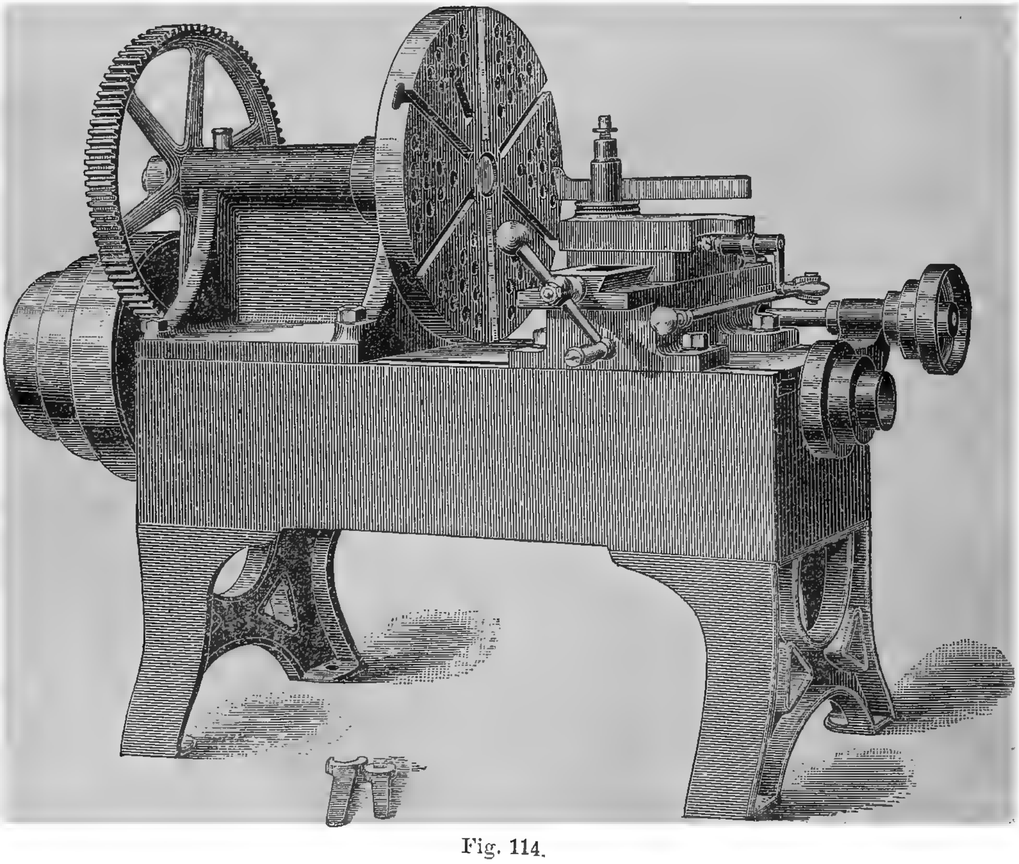


Fig. 114.

posts, and a facing-rest may be secured to the face-plates. Upon the tool-posts may be secured a quartering device for boring the holes for crank-pins at exactly 90° with each other. In other forms of this same tool the quartering attachments are secured to the frames, so that the spindle passes through the face-plates. The tool-posts clamp in place and are fed from overhead.

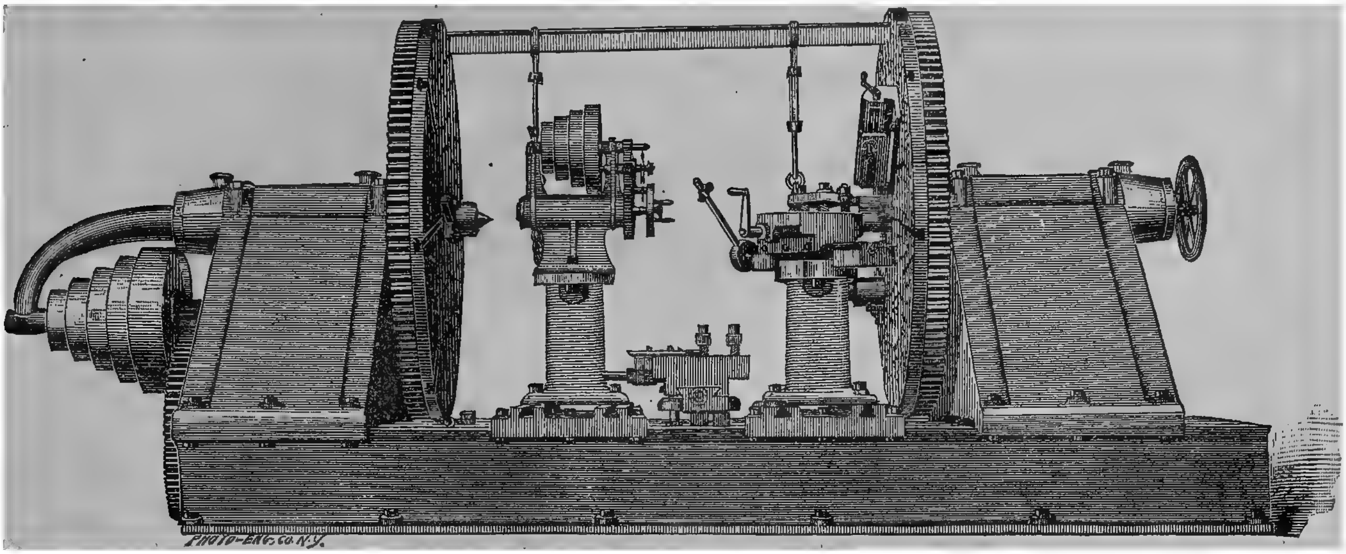


Fig. 115.

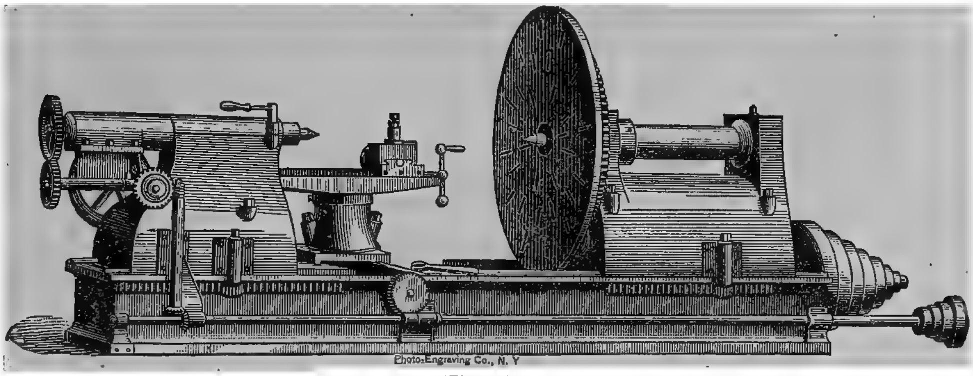


Fig. 116.

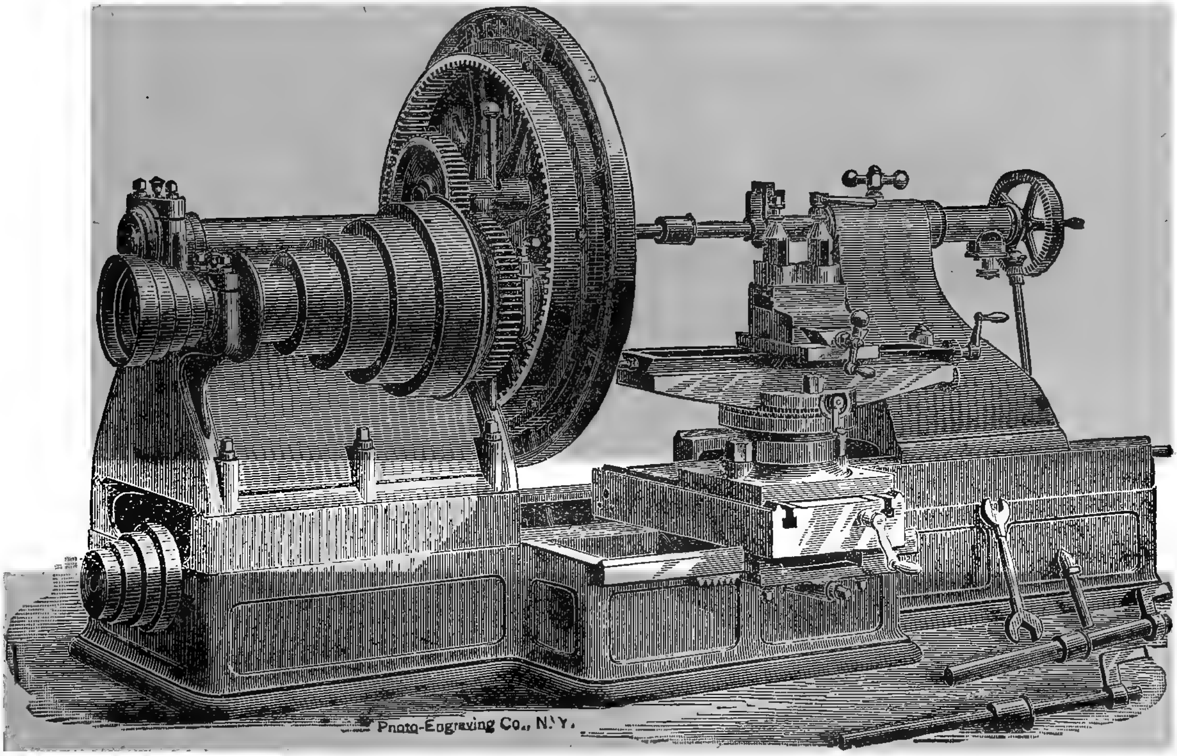


Fig. 117.

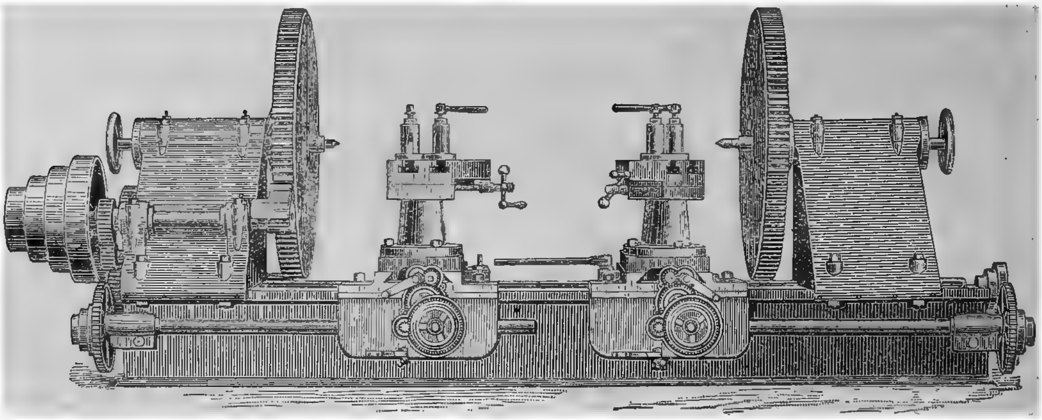


Fig. 118.

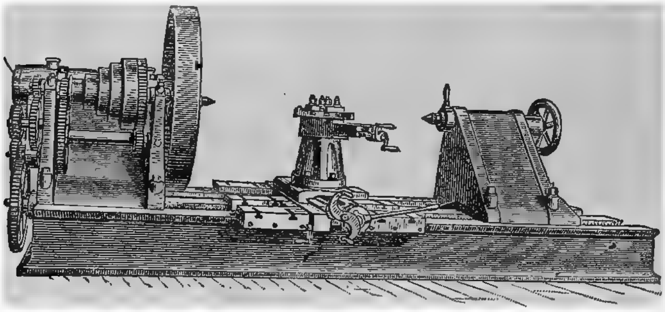


Fig. 119.

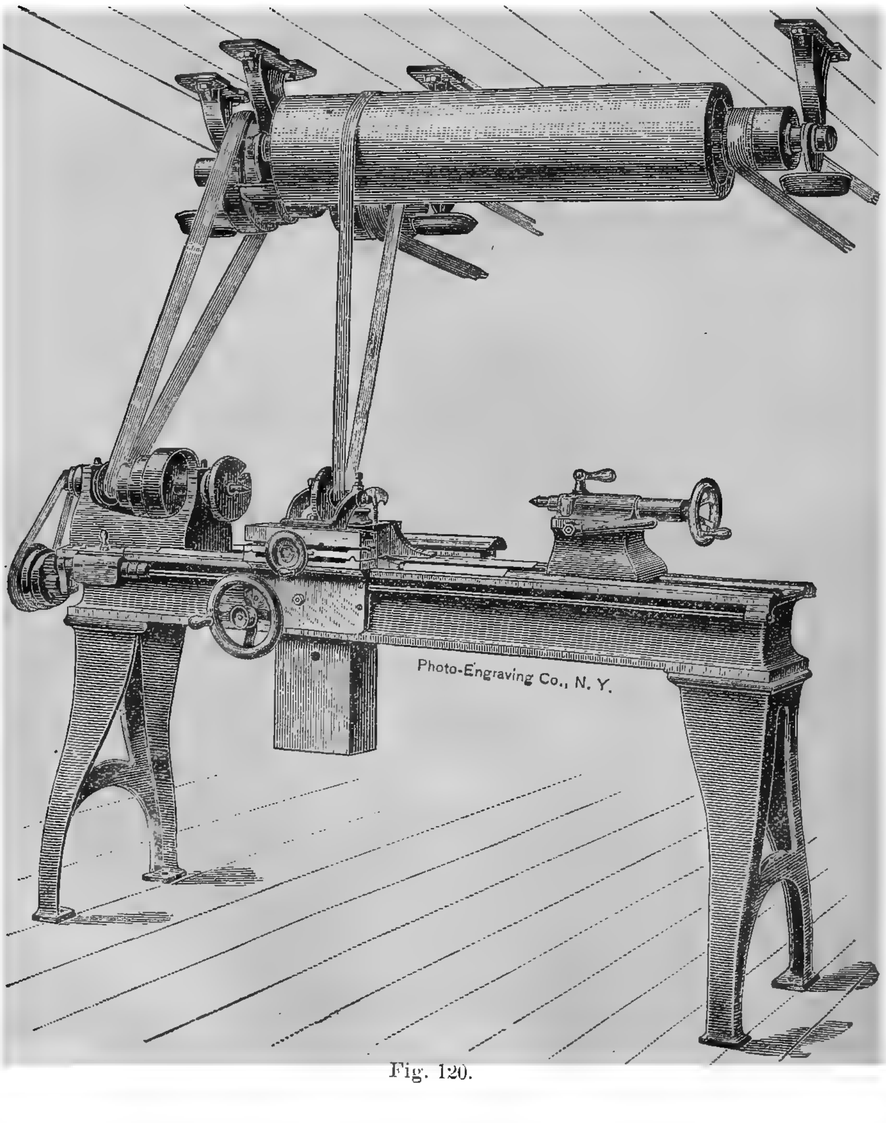


Fig. 120.

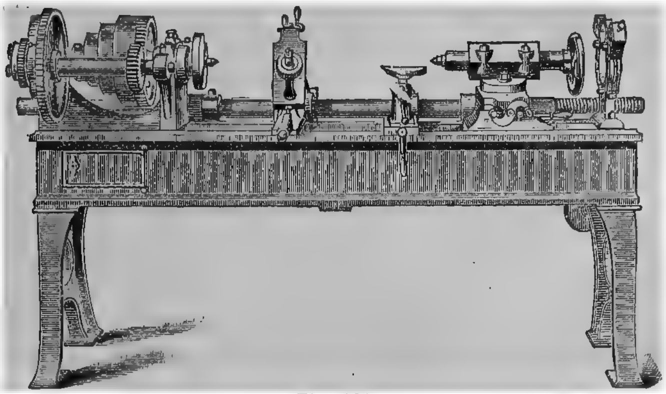


Fig. 121.

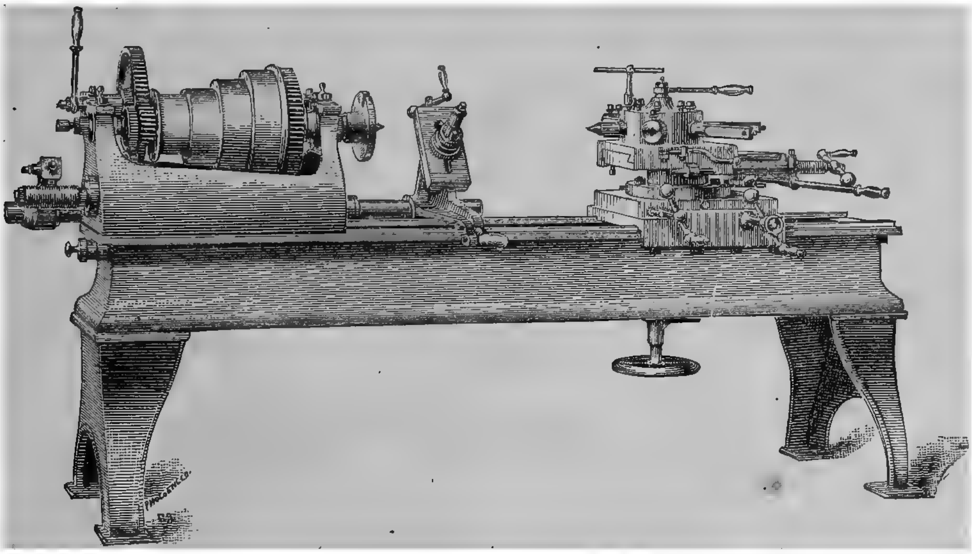


Fig. 122.

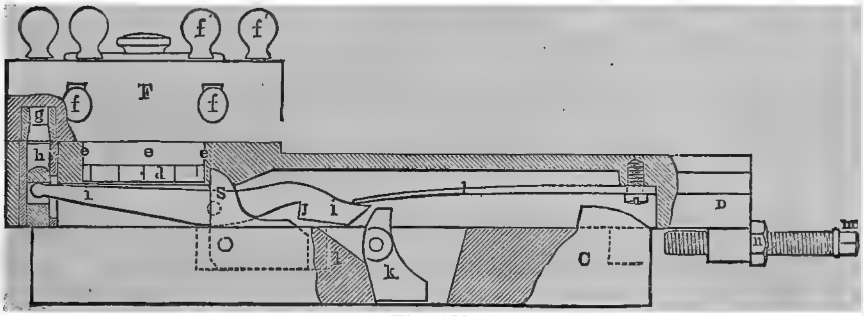


Fig. 123.

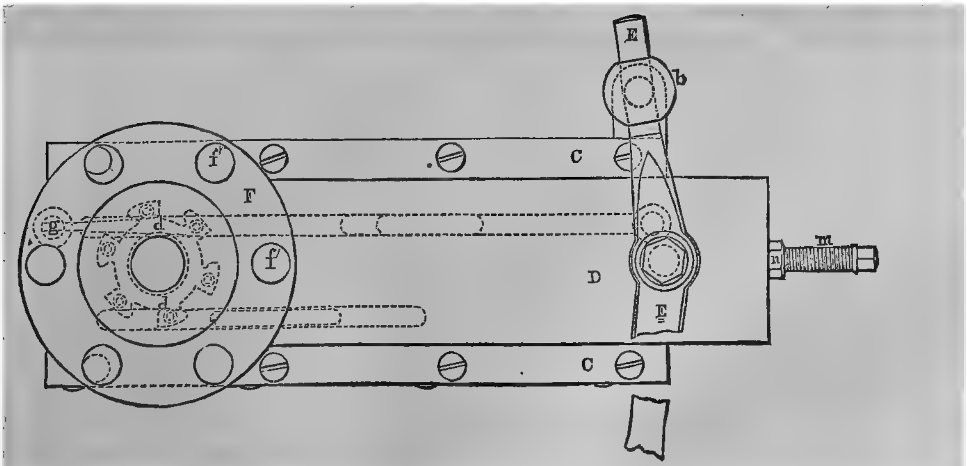


Fig. 124.

The lathe of Fig. 116 has one or two stationary tool-posts. The head- and tail-stock are both made movable by rack and pinion along the bed. The face-plate is driven from a splined shaft below the shears. The tail-spindle has power-feed for boring from the feed-shaft at the back. The feed for the tool is carried up vertically by bevel-gear through the center of the post, and at the top is carried to the feed-screws by double bevel-gear, giving motion forward or backward at will. The driving-axis, being central to the post, permits feed at any angle. The movable heads with stationary post gives great steadiness and stiffness. A slightly different tool with similar facilities is shown by Fig. 117. Figs. 118 and 119 show types of lathes of very large swing.

For the exact sizing of hardened steel spindles and the like the cutting has to be done by an emery-wheel. Fig. 120 shows the arrangement for such lathes, the grinding-spindle being driven by a separate counter-shaft, with a long drum. The shear-tracks are protected from the emery-dust by guards. The slide-rest has an automatic longitudinal traverse in both directions, the reversing being done by double bevel-gears and a clutch connected with the feed-rod. It can grind tapers as well as cylindrical surfaces.

For reduplicating small chucked work in the soft metals what is called a chasing-lathe (Fig. 121) is in very general use. It is not intended for turning work between centers, but it can be so used if desired. The head-stock receives motion in the usual way by cone-pulleys and back-gear. The tail-stock has also two motions, so that a tool can be inserted in the squared spindle, and by working the cross-feed to a stop any standard diameter can be reproduced without the loss of time for calibrating. It can also be set to cut tapers. The slide-rest is clamped upon a guided bar at the back, and is brought to its work by a handle, which is pressed down upon the front shear. The tool-post is fed upon an inclined shear by a screw. An arm on the guided bar carries a half-nut, which is brought into gear with a chasing-hob, driven from the live-spindle by the movement of the handle which brings the tool to its cut. The spindle carrying the hobs can carry two of different pitches, and a single-pointed tool can cut single, double, or quadruple threads. The slide-rest is counter-weighted so as to be brought up against a collar on either side at will when released from the chasing-hob. This collar can also serve as stop to prevent any given operation from being carried further than a certain length on the work. A hand-rest enables small finishing and chamfering cuts to be made by hand. A tool of this kind is adapted for miscellaneous work in brass, such as globe-valve and lubricator work, which it does very rapidly, exactly, and at one chucking.

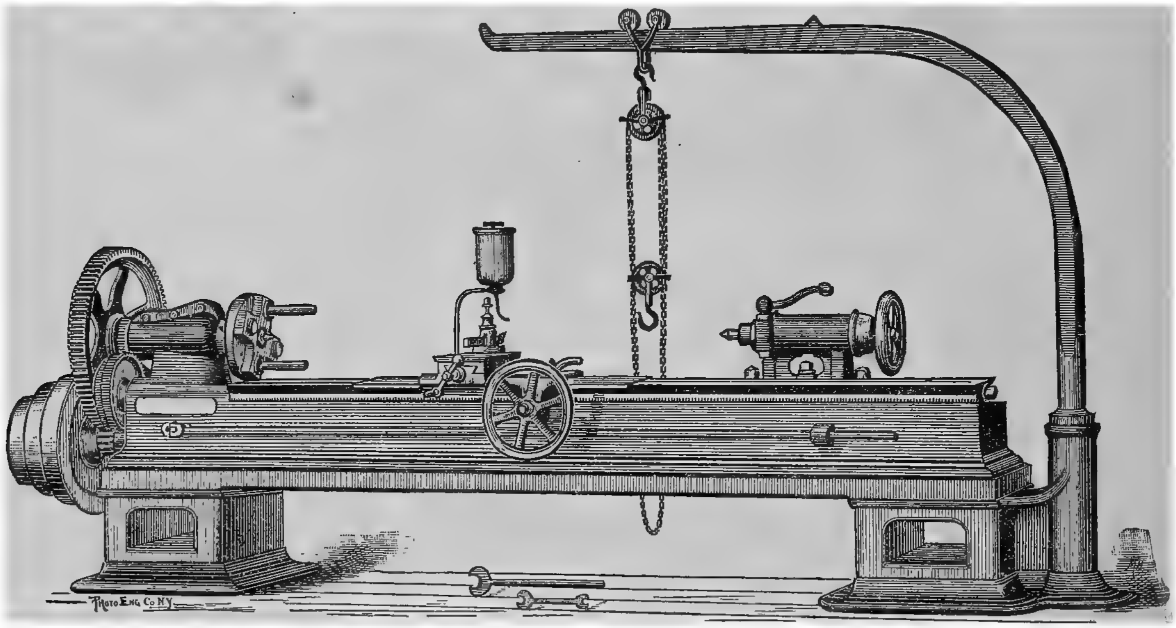


Fig. 125.

A similar tool, differing only in the construction of the tail-stock, is shown by Fig. 122. This tool is fitted with what is called a turret-head. A vertical cylinder, like a monitor turret, has six radial openings in the vertical surface, each of which carries a tool adapted for a different operation on the work. After the lower block has been clamped, the turret may receive its various motions by levers or by screws acting against adjustable stops. The interior construction of the turret-head and slide of one of the best forms is shown by Figs. 123 and 124. The lever E moves the slide D to the right and to the left. As the slide D carries the turret F to the right, the lug S strikes projections *d* on the bottom of the turret and gives it a partial rotation around its axis. That the proper amount of rotation may be given and the turret locked in the right place is the object of the pin *h*. This pin is thrown up into spaced holes in the bottom of the turret by the lever *i*, when it is released from the catch *k*. When D is moved to the right the pin is withdrawn from the hole *g*, and the end of *i* passes over the catch *k*. The movement of D in the other direction causes *i* to be released from *k*, and when the hole comes opposite the pin the

spring *r* forces the former upward and locks the turret. The pin and the bushing *s* of the holes are made conical, so as to come to an exact fit, and are hardened to prevent wear. In the lathe illustrated the disagreement of the centers, which is such an annoyance in turret-lathe work, is avoided by an especial device. The head-stock swivels, and at its juncture with the bed is a tongue which permits the head to be raised by the elevating-screw under the head while preventing lateral displacement. If the centers do not agree, standard tools in the turret will turn work out of size.

For turning locomotive- and car-axles an especial design of lathe is preferred. These are of two kinds, the single head and the double head. The single-head machine acts on one end at a time only. Such an one would

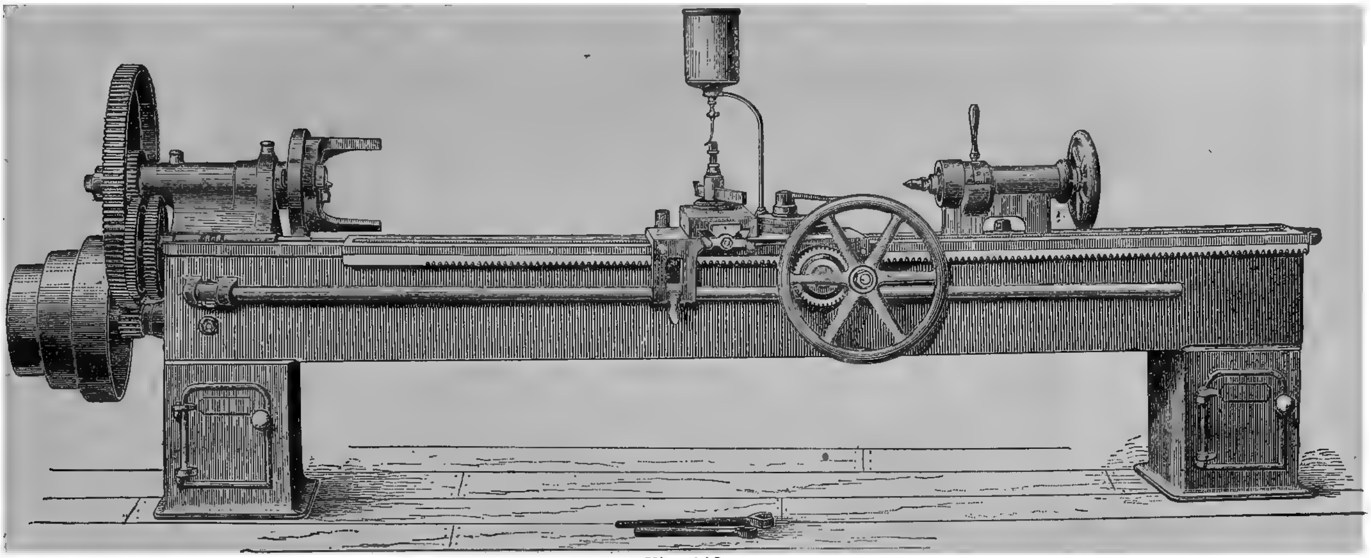


Fig. 126.

be illustrated by Fig. 125. The shears are flat, since the strain can come inside of them, the tail-head moving on a lower plane than the carriage. The head-stock is made adjustable for wear by the split in the casing, which is

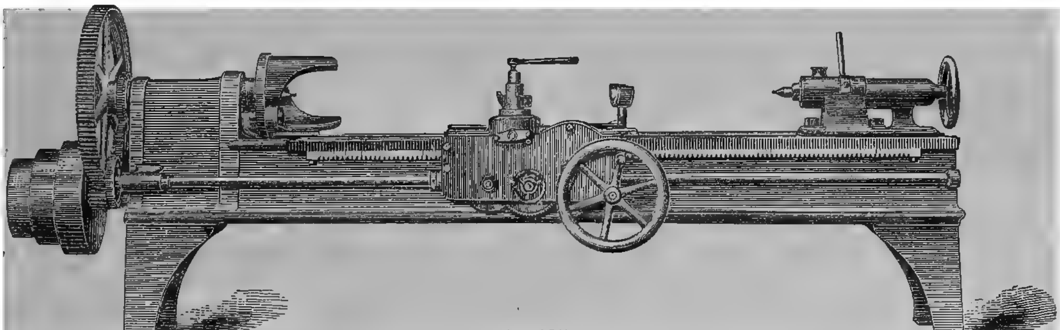


Fig. 127.

kept together by bolts. To equalize the turning strain on the axle when under the cut it is driven by two pins on the face-plate. There are two speeds of the tool for roughing and finishing which are caused by the two sets of pulleys on the counter-shaft. The two sets of feeds are produced at the head by the rod in front of the bed. The crane with differential pulley-gear enables the work to be handled easily.

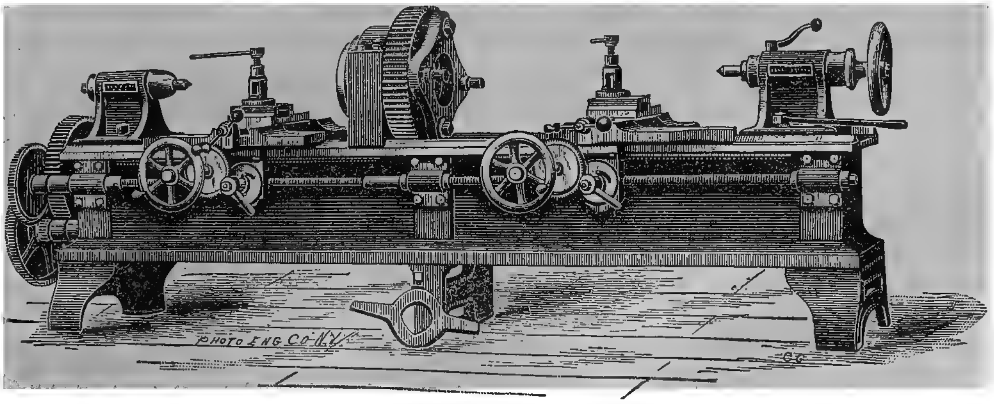


Fig. 128.

Differing only in some of the details are the car-axle lathes shown in Figs. 126 and 127. The lathe of Fig. 128 is one of the double-headed type. The axle is driven by a driver from the middle, and there is a tool-post for each

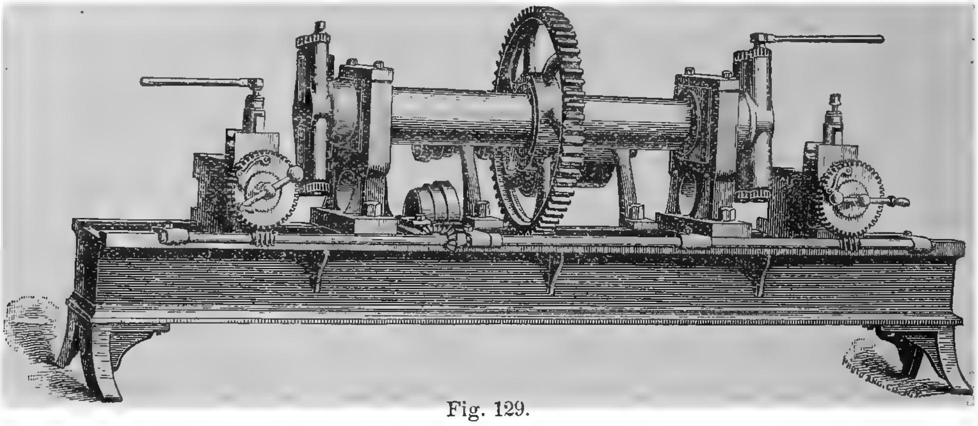


Fig. 129.

end, so that the two ends may be worked at once. The driving-pin plate is not rigidly bolted to the gear-wheel head, but has a certain diametral adjustment in slots. This enables the driver to be acted on equally by both pins,

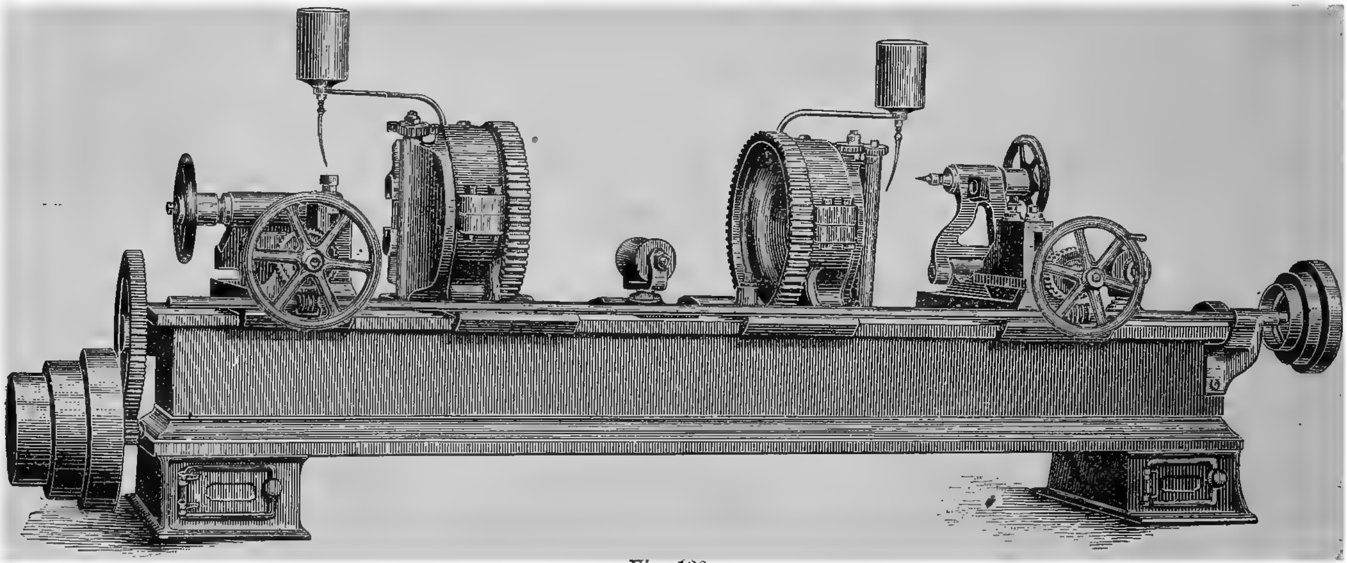


Fig. 130.

and avoids the tendency to spring sidewise which is not infrequently manifested when the axle is driven from a jaw-chuck. When this happens the work is out of round when released.

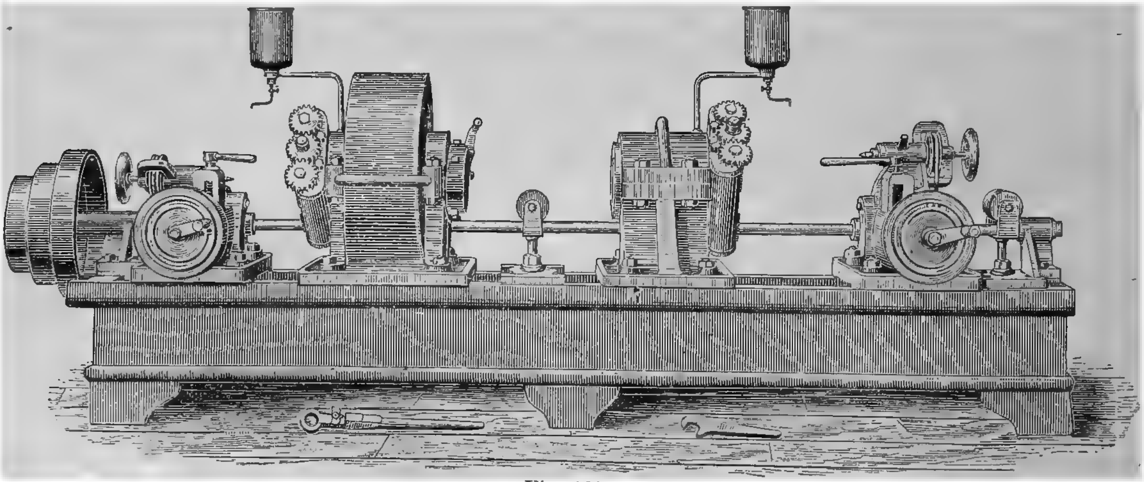


Fig. 131.

Another type of double-headed lathe is shown by Fig. 129. The axle is driven by jaws close to the cut, and the slide-rests have lateral and longitudinal power feed. By this system it is unnecessary to center the axles after being cut.

For cutting off and centering axles as they come from the hammer the tool shown by Fig. 130 is in use. The axle is driven at each end from the splined shaft within the bed, and cutting-off tools are fed against them at the proper length. When the crop-ends are removed the centering-heads may be fed into the end to drill and countersink for the center of the lathe which is to follow. The centering-heads can be swung out of the way when not in use. Fig. 131 illustrates another form of the same tool. A machine for centering only, after the crop ends have been removed, is shown by Fig. 132. The jaws are moved by right-and-left screw, and the center drill is fed rapidly by a rack and hand-wheel. An axle can be centered in three minutes by this machine.

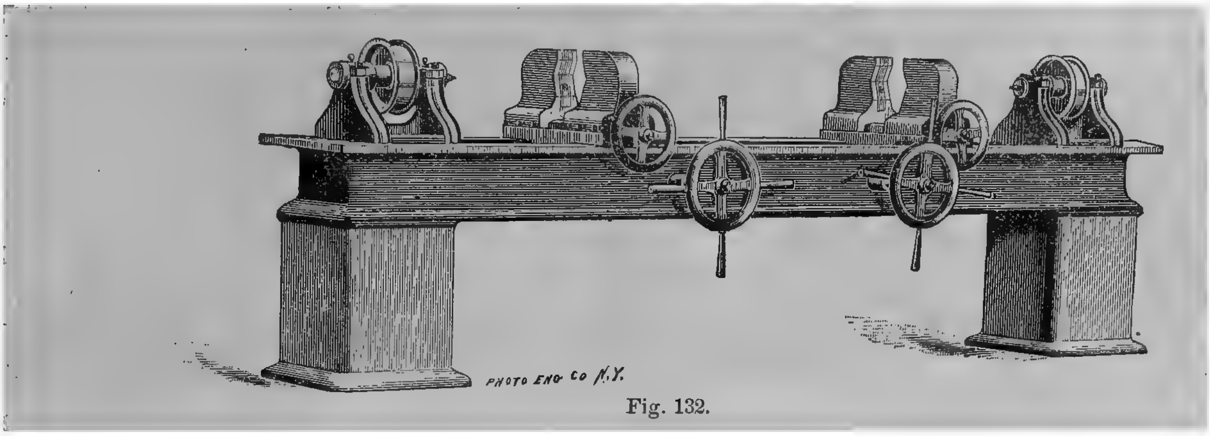


Fig. 132.

The lathe shown in Fig. 133 differs from the preceding in using a bed of a cylindrical section, with flats raised for the poppet-head and slide-rest. The feed is by a worm of four threads meshing into a rack on the front of the bed. The axle is driven by what is known as Clements' driver on the face-plate. The gearing is strong enough to rough out the journal in one cut of a depth of $\frac{3}{4}$ or $\frac{7}{8}$ of an inch. For centering the rough axle and sizing the wheel-fit the machine shown in Fig. 134 is used. The axle is driven from a powerful chuck lined with brass. This

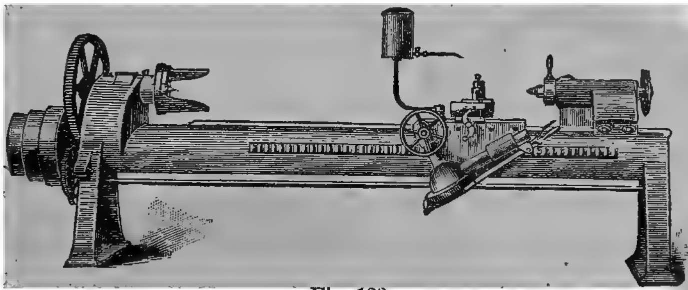


Fig. 133.

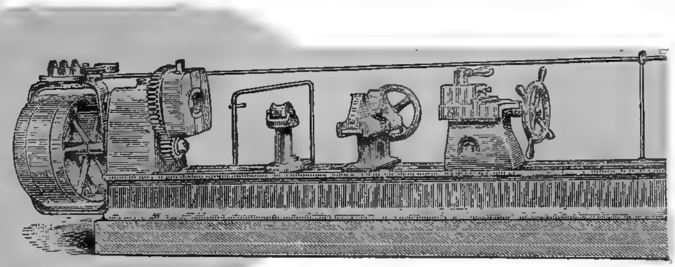


Fig. 134.

may clasp the axle by its collar when it is finished. The free end is held in an adjustable V-guide, and the end of the axle is squared and centered by a tool fed to it. The wheel-fit is sized exactly by a hollow reamer with adjustable blades. With these conveniences it is claimed that this tool and the lathe make it possible to produce from eighteen to twenty axles per man per ten hours.

With the lathes for axles should be discussed those lathes designed specially for finishing pulleys. Fig. 135

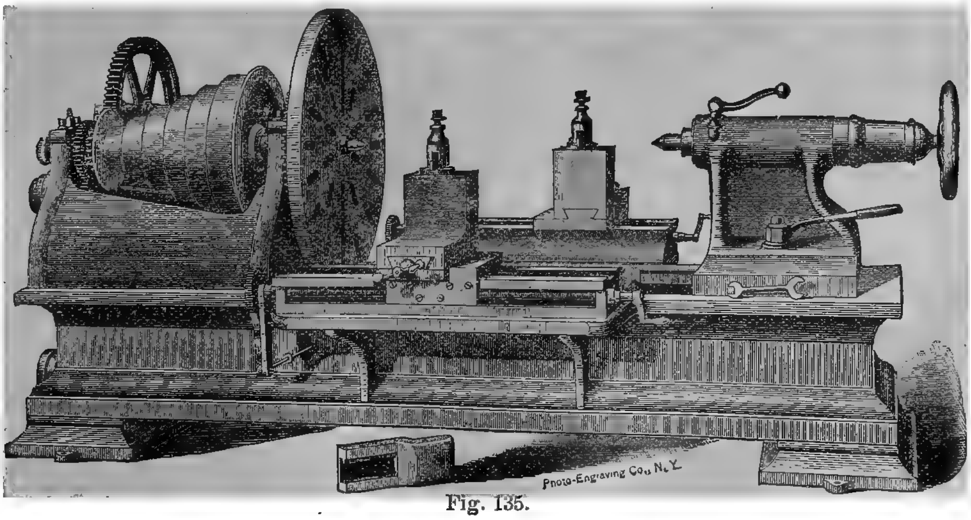


Fig. 135.

shows an ordinary lathe design of large swing, specially altered for pulley-work. The chief differences are in the use of two tool-rests of variable ratchet-feed, and in the arrangements to permit the face to be turned crowning.

Fig. 136 shows a special pulley-machine for taking bored pulleys on a mandrel. This system has the advantage over the chucking system of turning the pulley more under the same conditions in which it is afterward to be run on a shaft. The pulley is secured on the mandrel by its own set-screws or keys, although it is driven by driver-pins on the gear-wheel, resting against its arms. A former attachment will turn the face crowning. For filing or polishing the mandrel may be driven directly by the belt-wheel on the spindle.

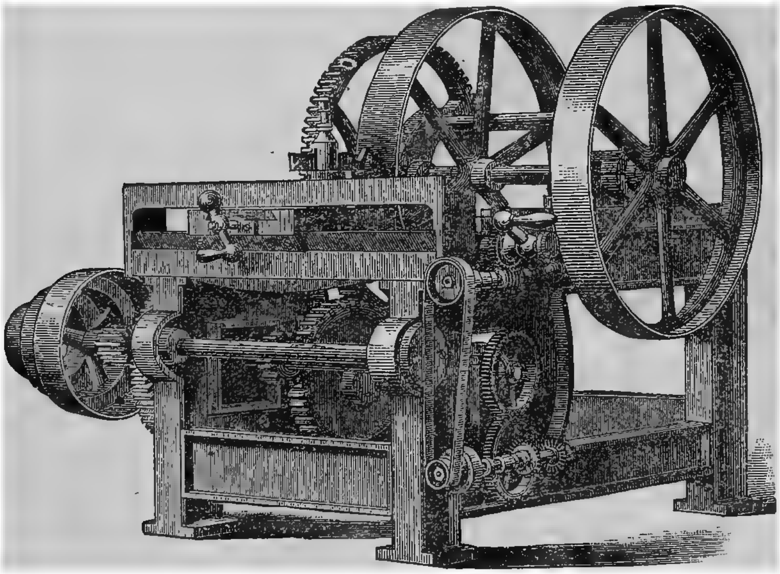


Fig. 136.

A similar tool is shown by Fig. 137, except that worm-gear is used to drive the mandrel, and the driver-pins are adjustable upon the face-plate to equalize the strain on the pulley-arms. The crowning is effected by setting over one end of the tool-post rail, according to the graduations. The worm-wheel on the feed-screw is relieved to permit this adjustment. The turned pulley is polished by securing it to the end of the worm-shaft, and the two operations of turning and polishing may go on at once.

Fig. 138 shows a double pulley-lathe on the mandrel system. The mandrel may be supported on a head with adjustable center, and the faces may be turned flat or crowning. Each slide has an independent self-acting feed, with automatic disengaging gear.

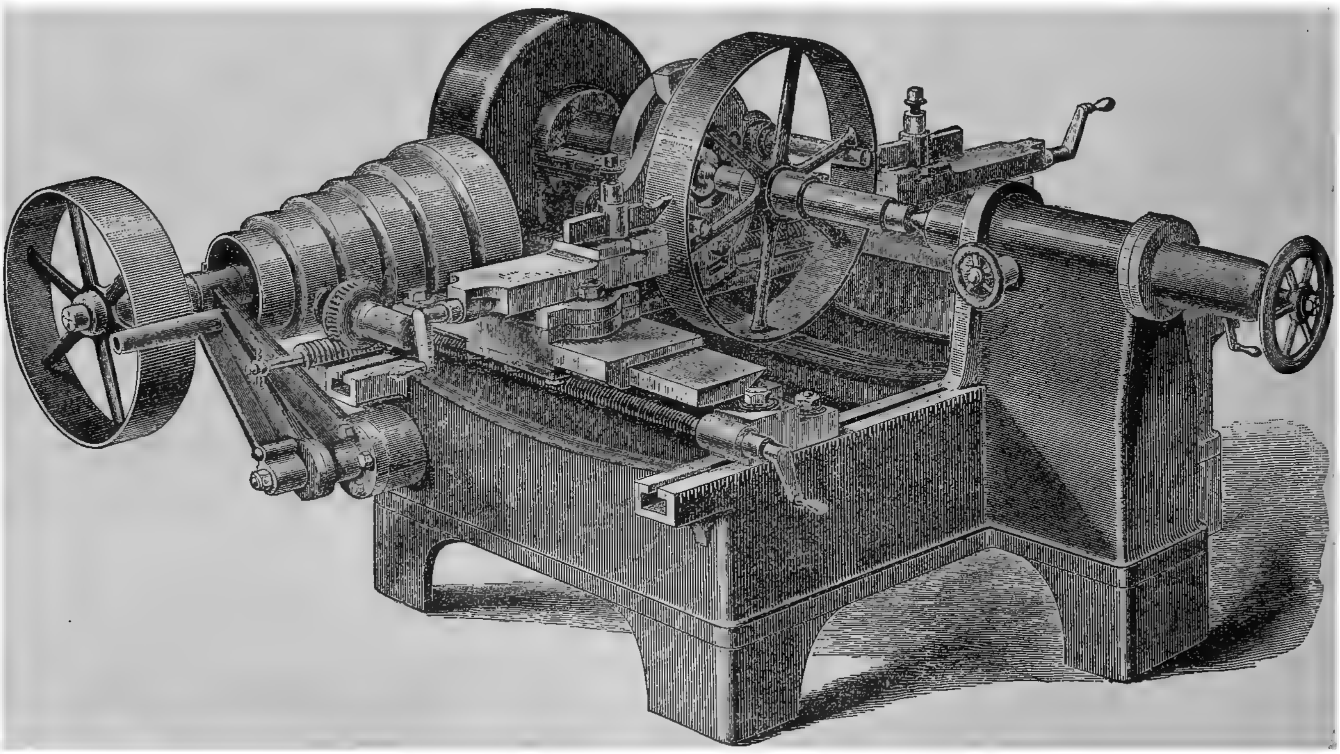


Fig. 137.

An objection to the mandrel system in these forms is that the pulley must first be chucked and the hole in the hub must be bored before the wheel can be put on the special lathe. This requires two tools, and some of the forms of boring-machine must precede the pulley-lathe.

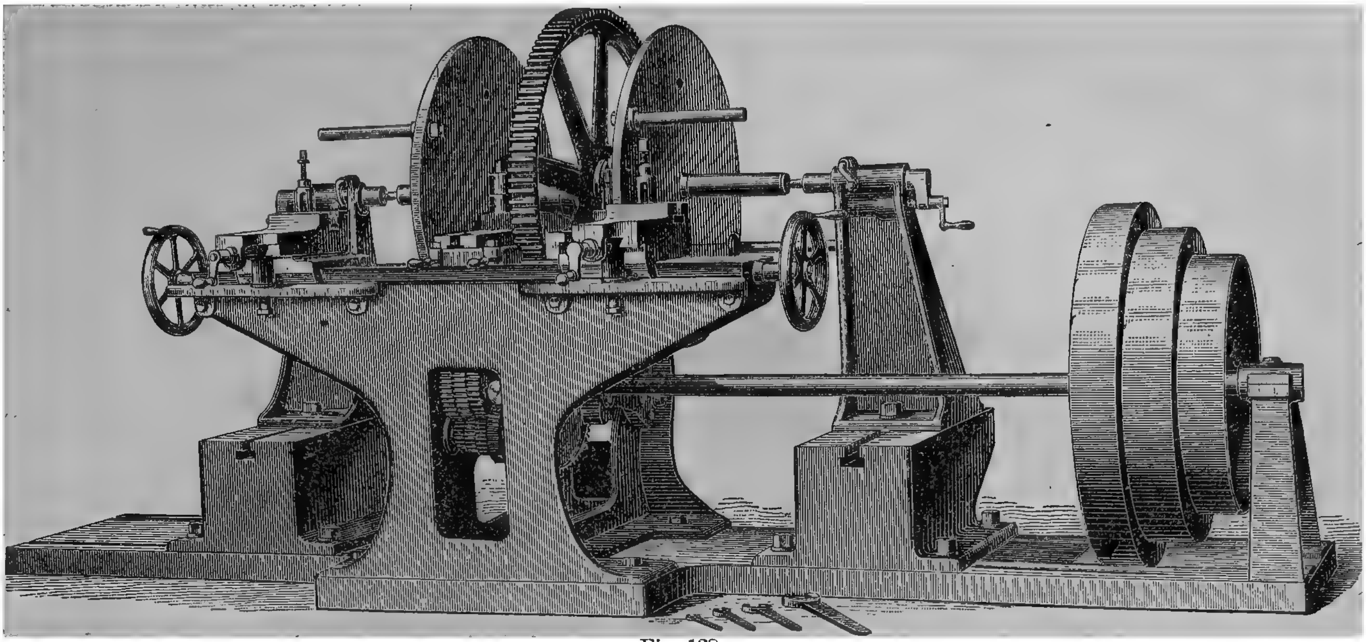


Fig. 138.

§ 18.

VERTICAL LATHES AND BORING-MACHINES.

The distinction between a lathe and a boring-machine is somewhat one of convention. Any lathe can be used as a boring-machine, either by securing the work to the chuck or by securing the work to the carriage and supporting a boring-bar between the centers. Especially is the distinction elusive when applied to the vertical machines. To carry out a possible analogy from the horizontal machines, a lathe would be a tool where the work revolved while the tool has only linear motions, while a boring-machine would be one in which the work was stationary and a cutting-tool described the surface of revolution. Many vertical lathes, however, on this classification are currently known as boring-machines, because they are designed for one class of work only, such as pulley or car-wheel boring-machines. There are certain of them which come unmistakably under the class of lathes, since they can turn as well as bore.

Fig. 139 shows one form of turning- and boring-mill. The work is secured to the horizontal face-plate and the tool is carried by the holder upon the cross-head. The feed of the tool is self-acting in all directions by the twisted belt at the right. The idle shaft, connected to the driving-shaft by a link, keeps the belt tight by its weight and permits the cross-head to rise and fall. The cross-head is only finished to guide the tool-post for a little over one-half the swing of the tool, since the cut is intended to be resisted by the compression against the cross-head. The slide on the cross-head is fed horizontally by the screw and vertically or at any angle from the splined shaft above the latter. The shaft carries a bevel-gear, which turns the rod parallel to the axis of the holder through an idle pair of bevel-wheels. As these mills have large capacity, swinging from 84 to 120 inches in the different sizes, the large face-plate must be steadied. This is accomplished by making a V-ring on the lower side of the plate which projects into and fits a corresponding V-groove in the bed. This makes the motion as steady as that of a planer bed. An adjustable step at the center can be made to take up any desired amount of vertical strain in the preliminary work of chucking and centering.

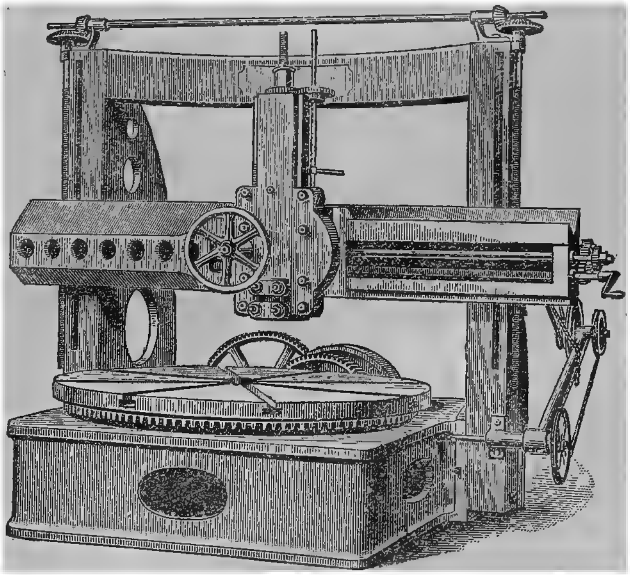


Fig. 139.

Fig. 140 shows a similar design, with two tool-holders. The holders are each counter-weighted by a weight on a wire-rope over pulleys. The rope winds on a pulley with a spiral groove at the back of the holder, the circumference of the pulley being in the axis of the holder. This prevents the action of the weight from departing very much

from the line of the action of gravity. The axis of the grooved pulley turns a pinion meshing into a rack on the side of the holder. The feeds for the tools are automatic in every direction and independent. The facing traverse is by screws which can feed in either direction. Their motion is received from the vertical shaft at the right, which

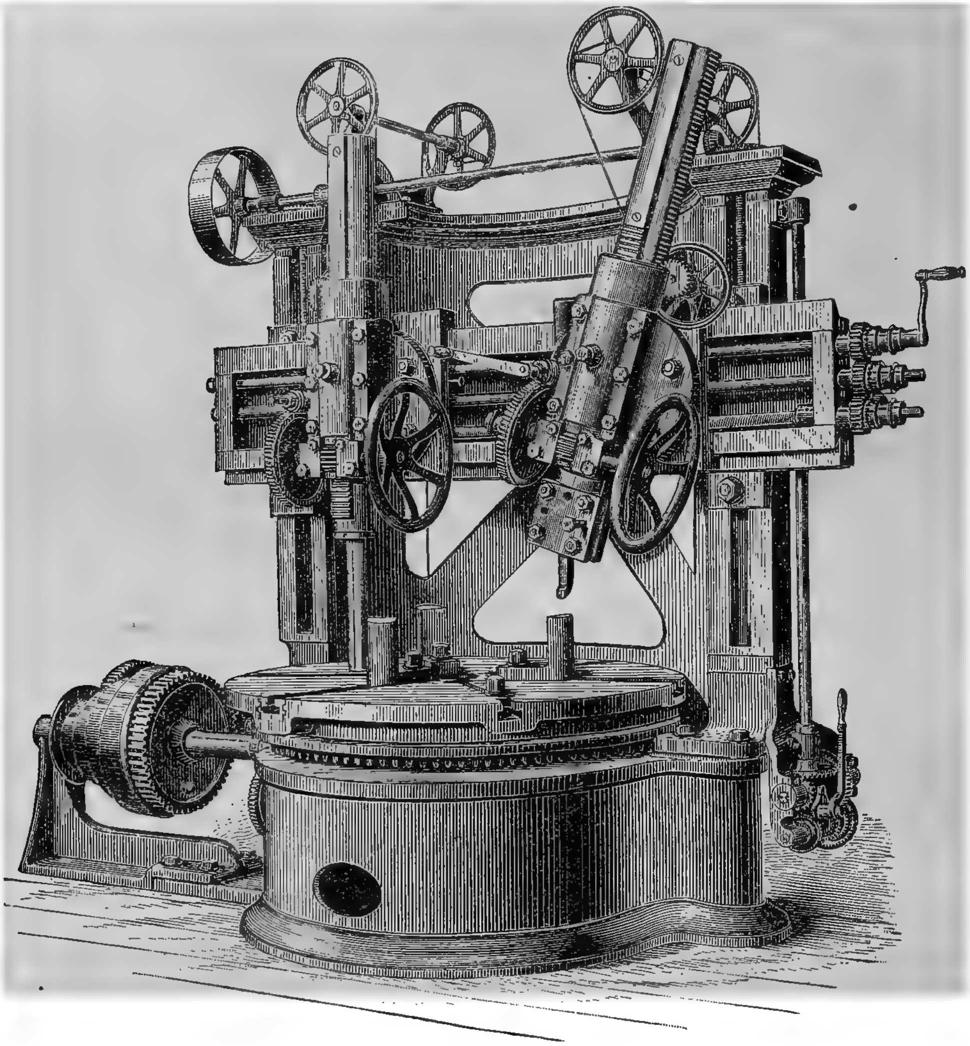


Fig. 140.

can be driven in either direction by the combination of three bevel-gears and a clutch from the cone-pulley shaft. Either cross-feed may be disengaged by a slip-jaw clutch on the end of the screw. For the downward and angular feeds the central splined shaft is used. A pair of bevel-gears, with clutch, is carried on the cross-slide. Between them is a third wheel, on whose shaft is a worm which turns a pinion-shaft and lifts and lowers the holder by a rack. The clutch to the worm-shaft is worked from behind the cross-head for change of direction, and the pinion-shaft is disengaged for convenient hand-feed and quick return by a slip-jaw clutch. The face-plate on the large sizes is driven by internal spur-gearing (Fig. 141) to avoid the lifting or bending action produced by bevel-gearing. The entire revolving weight is borne upon a central step. This consists of a loose steel disk, hardened and ground, which is placed between two others of a hard alloy of copper and tin. One is fast to the foot-step, and the other is on the revolving spindle. These disks are grooved for the distribution of oil, delivered through a tube under the center. Chips are kept from the lower bearing by guards.

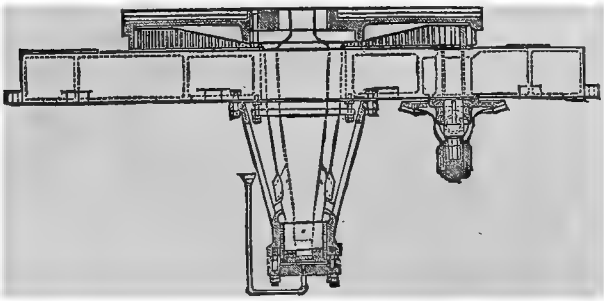


Fig. 141.

By the use of two holders a piece of work may be exposed to two operations at once. A pulley may be faced and bored at the same time, or a ring may be turned and faced at one operation. In another design the down-feed is given by a worm and wheel in front of the holder. The worm is driven by extensible shaft and universal joints for turning tapers. These tools are also made up to 12 feet swing. Some of the smaller sizes have the face-plate carried on a Schiele anti-friction curve, and a slotting attachment may be added for pulley-work.

A similar tool to the latter is shown by Fig. 142. It has the adjustable step for the spindle, controllable by the screw in front of the bed. The feeds are made variable in speed and direction by the brush-wheel combination at the right of the bed. The movable wheel is faced with leather, and adjusted by the hand-wheel. The tool-bars are counter-weighted, so as to have the pull of the weight always in the line of the axis without oblique stress on the guides. For pulley-work the adjustable driver-plate and carrier-pins are employed, and an adjustable dead-center is made use of. By setting the bars slightly oblique and feeding in opposite directions the pulleys will be

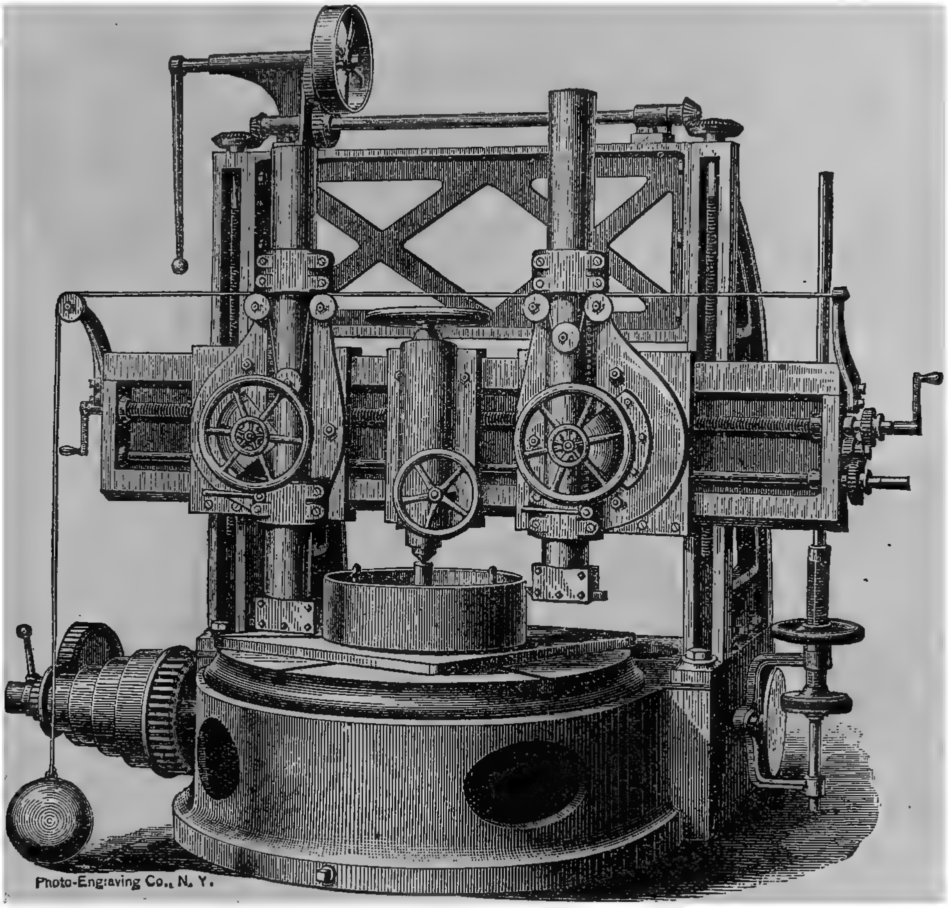


Fig. 142.

faced off with a crown. These tools are built of sizes to swing from 5 feet to 16 feet in diameter. In common with the other vertical lathes these tools have the advantage of simplifying the labor of chucking large and heavy work. All the time required to secure the work for the tests of its position on the face-plate is saved. The work will lie by its weight on the horizontal bed until located, while, when gravity has to be overcome on a vertical plate, the piece must be bolted fast. This property, with the conveniences of the double tool-bar, makes these tools of very wide and general usefulness. By removing the uprights of a very large mill of this class it may be used as a fly-wheel lathe for the largest diameters. The tool is held on a special upright on a floor-plate, and is fed by hand. Many drawbacks of the old chucking-lathe are thus avoided.

A very large number of vertical lathes of small swing are made for boring only and for special work. A type of these is shown by Fig. 143, adapted for boring-pulleys and car-wheels. The stiff boring-bar, counterpoised overhead, is held in the long adjustable bearing. It is fed downward by rack and pinion, driven by worm and wheel. The hand-feed quick-return is released by a friction-clutch. Specially for car-wheels the same builders have the tool shown by Fig. 144. The crane attachment is very convenient for chucking rapidly. Such tools are made with chucks of the self-centering and independent-jaw variety. They have capacity for wheels of 42 inches diameter.

Another form of car-wheel boring-machine is illustrated by Fig. 145. The adjustment for the bearing of the bar is effected by tightening the bolts upon the split casting. The counterpoising of the bar is by means of the weighted lever, which has a floating fulcrum to avoid side strain. The face-plate is adaptable for boring tapers, for the few conical fits which are used by some. It is made of two disks, the faces of both being beveled as they lie together. By changing the relation to each other of these two disks the horizontal adjustment is destroyed and a conical hole is bored. There is also a hub-facing attachment. The boring-mill of Fig. 146 feeds the tool down by a different mechanism. The hub-facing attachment has a slide independent of the boring-machinery, so that a

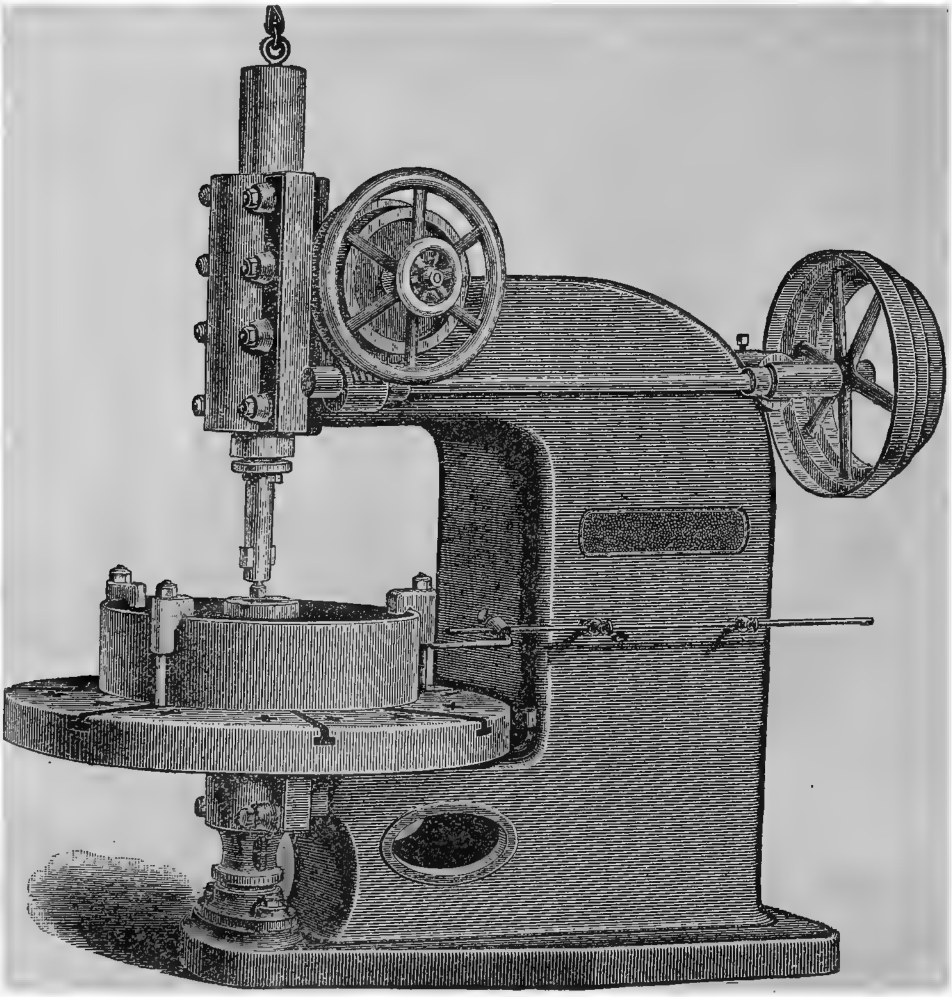


Fig. 143.

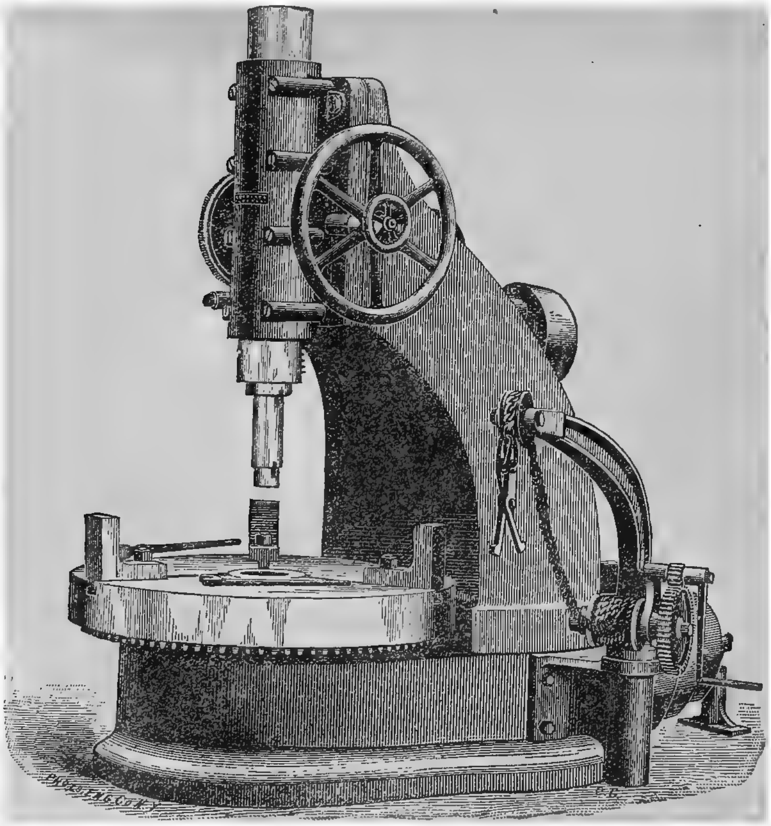


Fig. 144.

hub may be bored and faced at the same time. The crane attachment for lifting the wheels is hung from a davit overhead. It is a geared hoist. This machine has a claimed capacity for fifty wheels per ten hours.

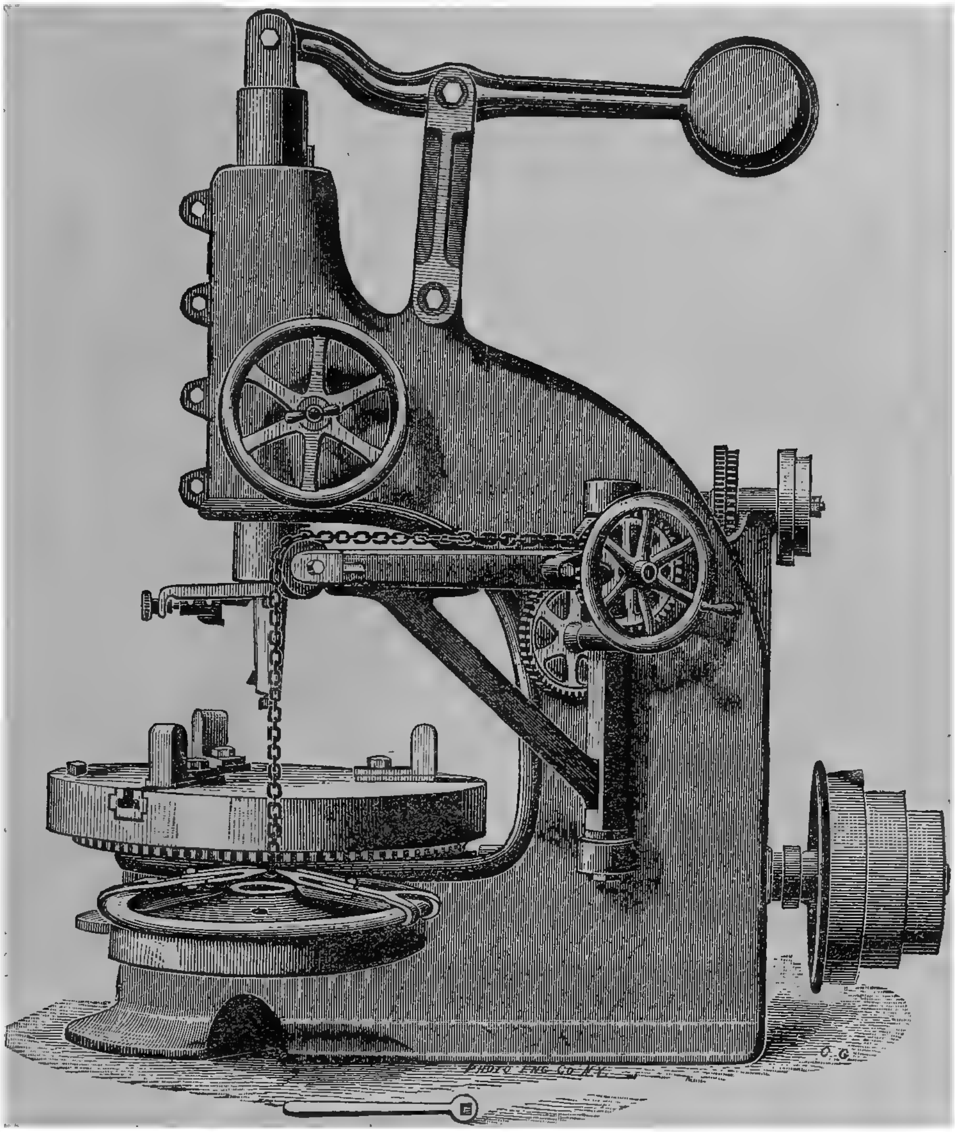


Fig. 145.

The borer of Fig. 147 takes up any lost motion around the bar by the glands at the top and bottom of the long bearing. These compress centrally a conical split sleeve when tightened down. The face-plate is carried upon a Schiele curve bearing, with a shoulder and ring at the top to prevent lateral jarring. The feed is by rack and pinion through worm-gear, engaged by friction. The gears are all external but boxed from dirt and accident. The roughing cut which should size to within $\frac{1}{32}$ of an inch is made with a feed of $\frac{1}{4}$ of an inch. The finishing cut is made with a feed of $\frac{3}{8}$ of an inch. By this machine a wheel can be chucked and bored in four minutes, as against seven minutes in the previous forms. The lifting-crane is also driven by power at the back.

For smaller work than this the table-borer (Fig. 148) is in use. The boring-bar is steadied and held by a counterpoised cross-head below the table. The feed is varied in either direction by the friction-disks between the desired limits, exactly as in the lathes of the same builders. The objection to these disks is their tendency to wear into rings, because of the sliding action where they overlap. All the borers of this type use the double cutters wedged into a slot in the bar (Fig. 149 *a* and *b*). The roughing-cutters wear more rapidly of course than those used for finishing. The first will probably lose its edge after boring four or five wheels; the other will last for more than ten times that number.

In all these forms of tool the horizontal chuck-plate permits very rapid adjustment of the wheels in place. Light hydraulic cranes are sometimes arranged to accommodate a number of tools, without requiring a special one for each.

For the boring of large vertical cylinders large shops usually have an especial apparatus, put up most frequently in a corner. A heavy boring-bar carries a spider or tool-carrier, which is moved up and down by a

screw in the deep spline which compels the rotation of the carrier (Fig. 150). A large gear drives the bar and the carrier-head, and reducing gearing feeds down the screw. Sometimes the feed-gear is driven by an epicyclic

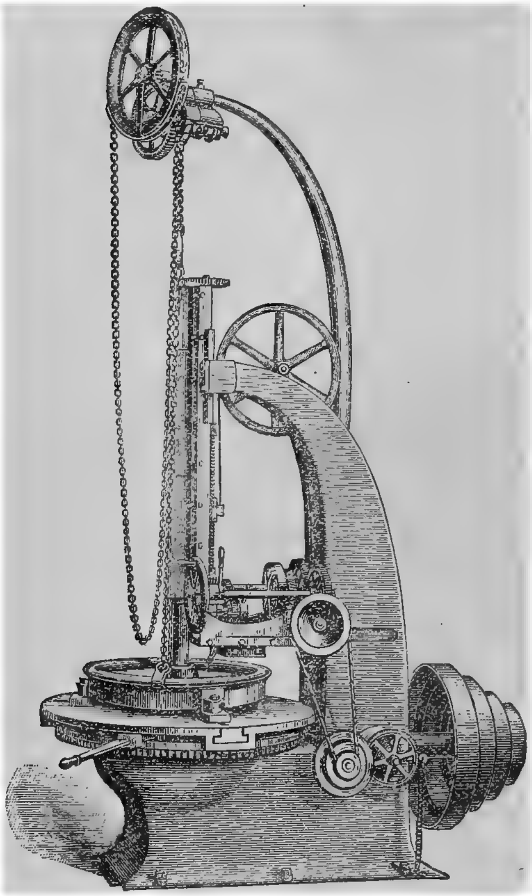


Fig. 146.

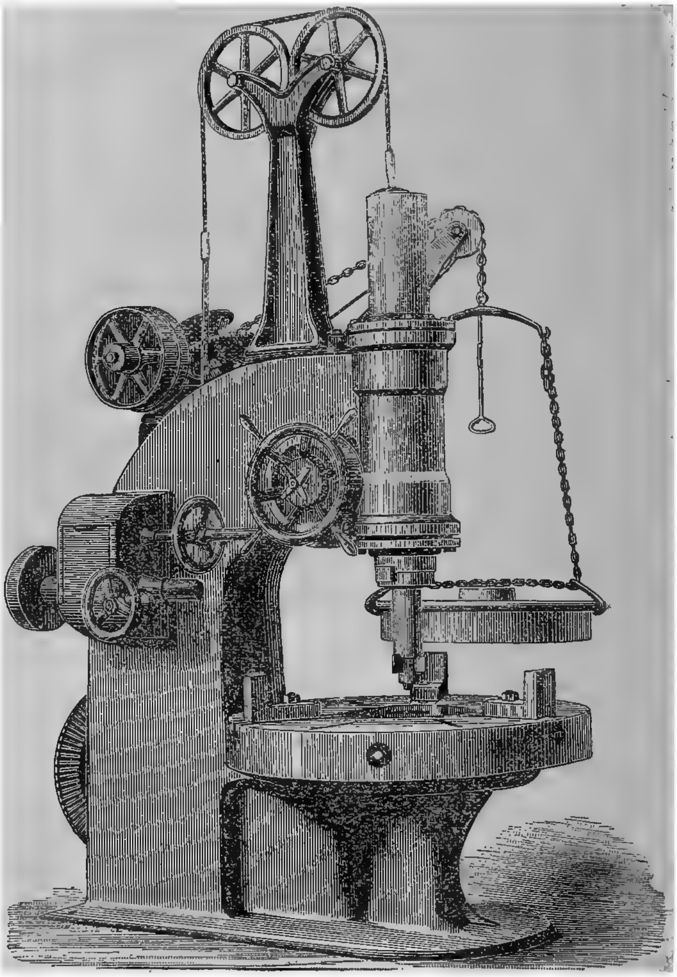


Fig. 147.

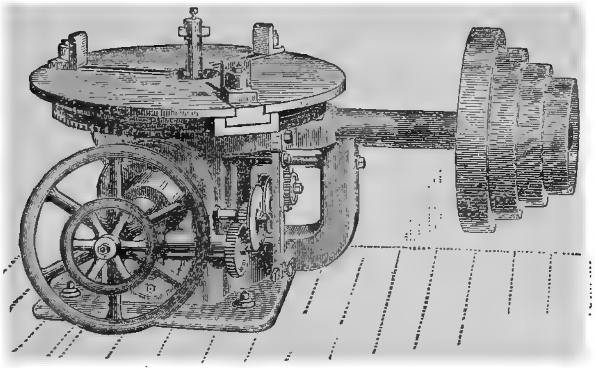


Fig. 148.

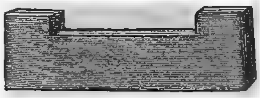


Fig. 149 a.

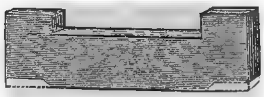


Fig. 149 b.

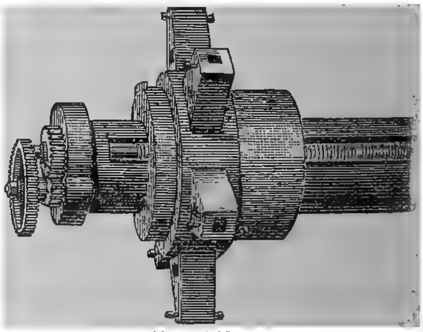


Fig. 150.

train. The cylinder is dogged and braced to a floor-plate at truly right angles to the bar. These machines have capacity for the largest cylinders.

§19.

HORIZONTAL BORING-MILLS.

The horizontal mills are especially adapted for bar-boring, either between centers or in bearings. The work is dogged to a table or carriage, which may be automatically fed or not, the feed in most cases being on the cutter-bar only. This type of tool is especially adapted for work in which the axis of the hole to be bored is parallel or not perpendicular to the chucking surface. It therefore lends itself easily to the boring of journal-boxes and hangers, of horizontal cylinders for engines and pumps, of elastic cylinders, and of cylinders without flanges, and work of that class.

For bar-boring between centers the machine of Fig. 151 is a type. The live-spindle is strongly back-geared,

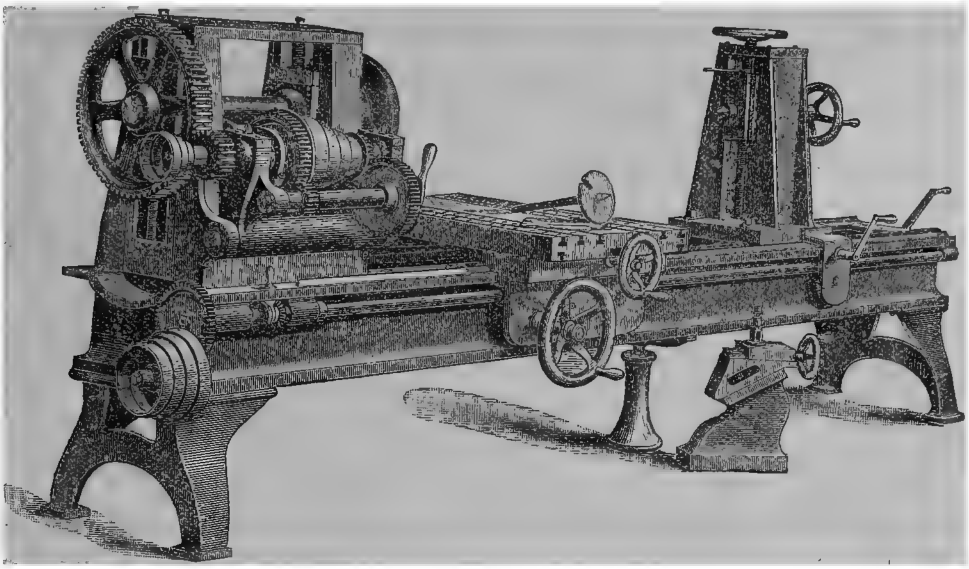


Fig. 151.

turning in long bearings at each end. The bearings of both head- and tail-stock are lifted by screws geared together by bevel-gears to a longitudinal shaft under the shears.

This arrangement insures that the two centers shall always remain in line. The hand-wheel at the dead-center permits accurate adjustment. The carriage is compound, having a longitudinal motion in either direction by power, and a cross-feed by hand. The power feed is reversed by a clutch between two bevel-gears. In some forms of this tool, when using a compound boring-bar, the carriage and work are stationary and the feed of the carrier is moved by a star-wheel on an arm from the head of the bar. Like any boring-mill with centers, this tool can be used as a lathe by simply bolting a tool-post to the slotted carriage; and conversely, of course, any lathe can be used as a similar bar-boring mill. This tool has the advantage over the lathe, in that the work does not have to be blocked up into the axis of the centers. The work can be bolted to the carriage, and then the centers can be rapidly adjusted into place.

For bar-boring in journals, and for horizontal drilling, the type of machine shown in Fig. 152 is used. A column supports a head like a lathe poppet-head. The spindle is long and has a longitudinal traverse. It is heavily back-geared, and is fed forward by a screw driven by friction-disks. This permits wide variation of feed for holes of different diameters. There is also a hand-feed over the spindle. The front end of the spindle is bored tapering, and can receive either a drill or the end of a boring-bar. The table in front is carried upon screws which are moved together by a hand-wheel convenient to the operator. The carriage has a longitudinal traverse, by a screw moved by the second hand-wheel, and also an adjusting cross-traverse. For the use of a boring-bar, an adjustable bearing to steady its outer end may be clamped on the carriage. More frequently, however, when bar-boring is to be done, the yoke-system is preferred (Fig. 153). The hole in the top is in the center line of the spindle, and can be bushed for different diameters of bar. It can be bolted to any part of the bed-plate for different lengths of bar, and also serves to steady the free end of the table. The front of the column carries the long gibbed knee of the table, giving great stiffness when at work. The thrust of the spindle is taken up at the collars which embrace the bracket at the back. This bracket is guided at its foot, below V-guides, and is fed forward by a rack. This rack is driven by a worm and wheel, which is engaged with the hand-feed and quick-return by a friction-clutch. There are six changes of feed, three of which are for drilling and three for boring. The slowest feed will permit small holes to be drilled in steel; the fastest gives $\frac{1}{4}$ of an inch feed for finishing cuts in boring. The cut shows

the raising and lowering gear driven by power. The tool may be run forward and backward at the same speed, so as to cut in either direction with the same cutters. The back-gear is compressed for ease of handling and compactness.

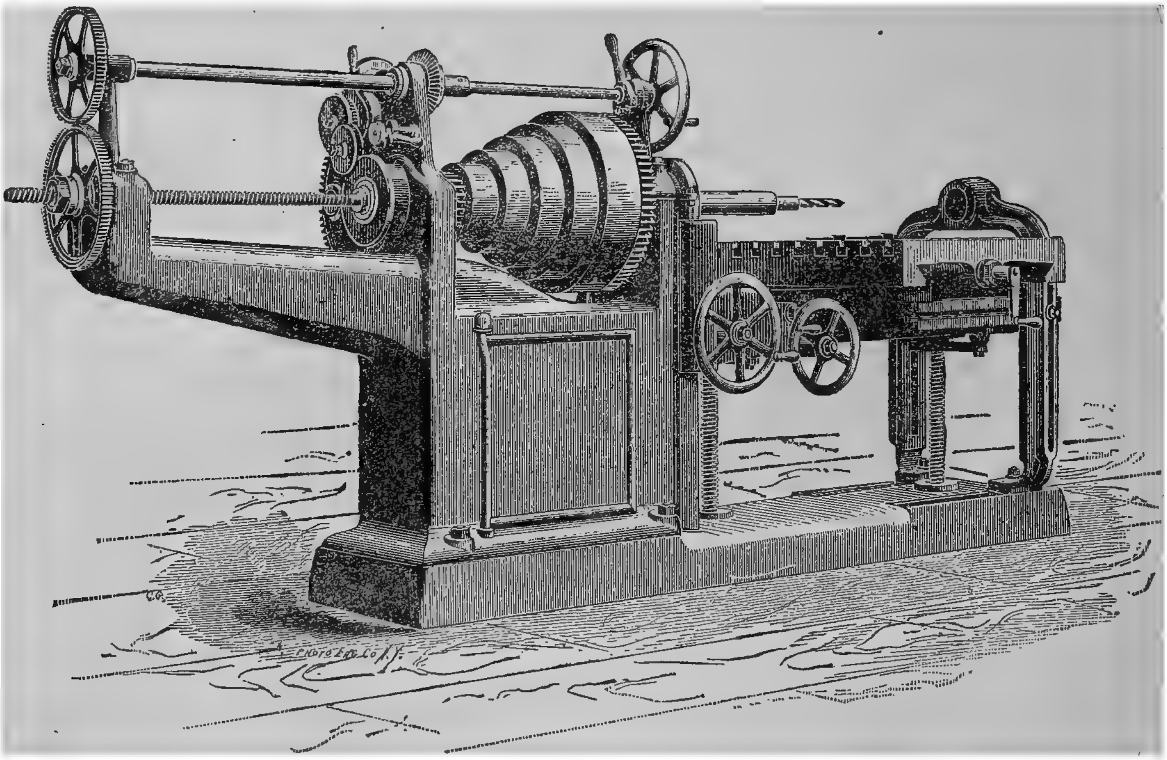


Fig. 152.

Fig. 154 differs only in the arrangement of the feed-gear. On one of the shafts are three loose gears. Each has a keyway cut in it. On the shaft is cut a spline till it meets a hole in the axis, in which slides a rod from the end. A key, fixed to the end of this rod, may be moved along the cut spline so as to come opposite the key-way in any of the gears, when it will slide into it, and make that gear fast to the shaft for the time. There is also a

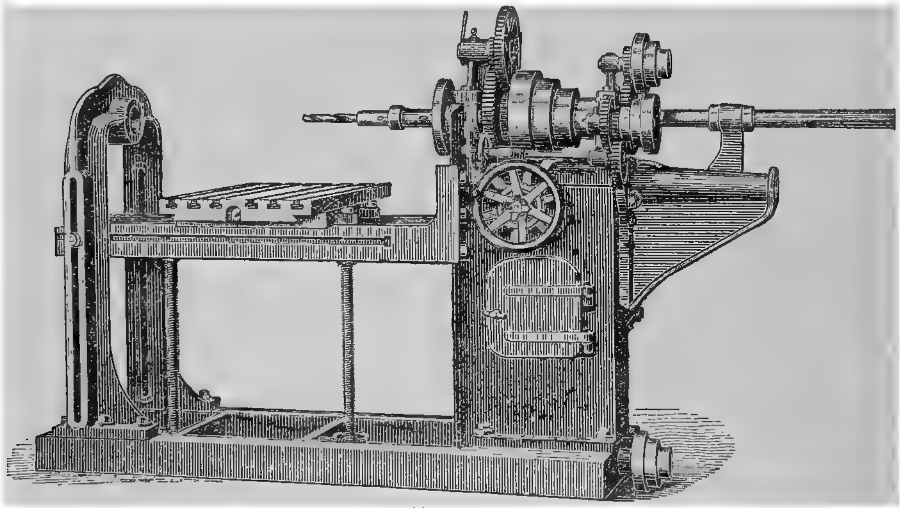


Fig. 153.

slow hand-feed and quick return. A facing-rest may be bolted to the face-plate, and will be fed by the star-wheel. The driving-pins are lightly bolted to the top of the head-casting. The thrust is taken up as before by collars against an arm from the guided slide, but in this design the arm is quite short. Sometimes a tail-screw is arranged on the slide to take up lost motion and to receive the thrust.

Where the work to be bored or drilled is very large or heavy, it is convenient to bolt it to the floor and to move the live-spindle into the proper position. Such a design is illustrated by Fig. 155. A large floor area is covered by a sole-plate with intersecting T-slots planed in it. In any position on this plate may bolt the lower

block of the spindle upright. The upright has an adjustment laterally on guides upon this block for distances less than the intervals between the slots. The spindle may be clamped at any elevation above the plate within

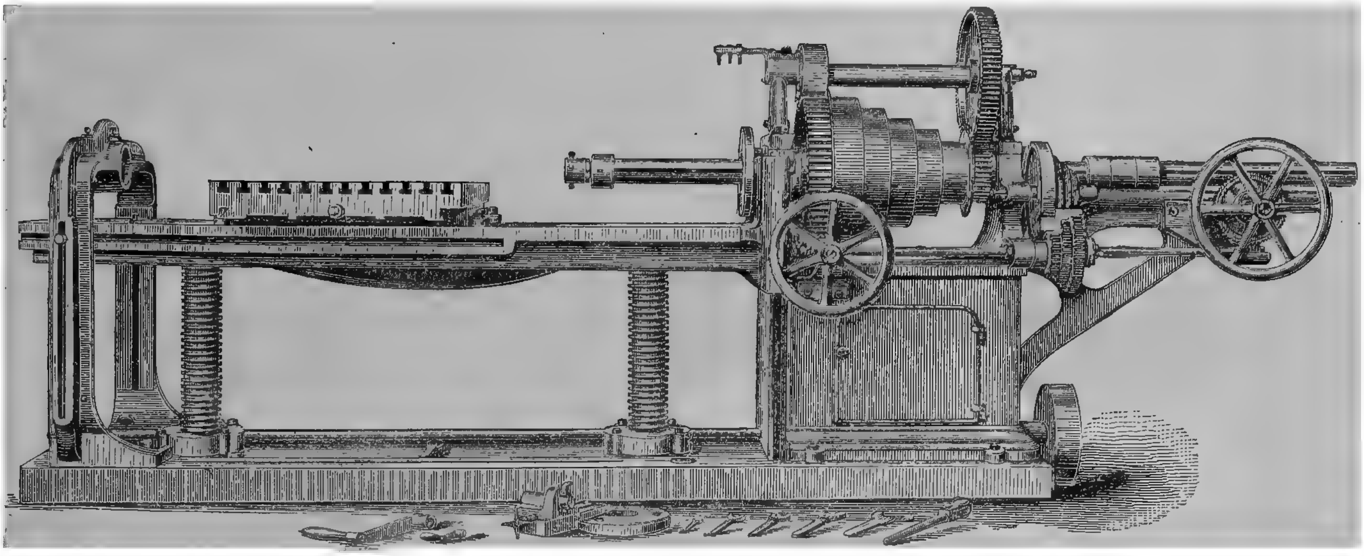


Fig. 154.

the limits of 6 feet 4 inches, and 14 inches. The casting is raised and lowered by screws driven by power. The power is transmitted to the tool by belts from swinging frames to take up the slack of adjustment. The bar is fed by a screw driven by friction-disks. To support the outer end of the bar a similar, but smaller, upright may be used, bolted to the slotted table where needed.

Another tool, with greater vertical capacity but less convenient horizontal adjustment, is made at Providence, Rhode Island. A tall upright, 15 feet high and braced from the roof, carries the gibbed slide with the horizontal

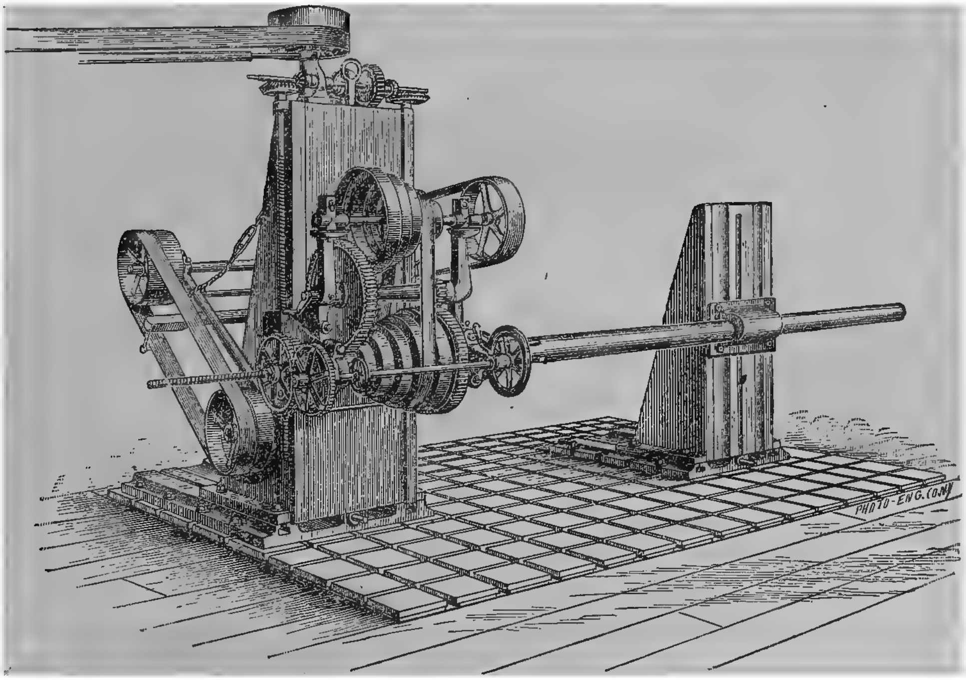


Fig. 155.

driving-spindle. Motion is imparted to the spindle by a pair of brass bevel-gears, the vertical shaft being splined and moving upward with the slide. The spindle is made long, and the thrust and feed are provided for by an arm from a guided slide. The feed is by hand and power, the adjustment of the slide being only by hand. Its weight is counterpoised. To secure the work a heavy table moves transversely on rails, the adjustment being effected by a pinion in the table taking into a fixed rack on the floor. There is no outer support for a long bar at high levels. The machine is more used for drilling, or for boring with short tools held in the end of the spindle.

A special tool for boring and facing flanged cylinders for locomotives and other engines is shown in Fig. 156. A 6-inch steel boring-bar is driven at both ends by the face-plates from a splined shaft in the bed. The bar can

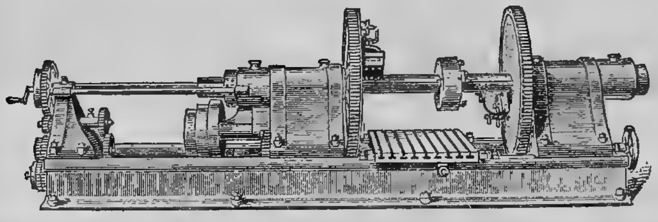


Fig. 156.

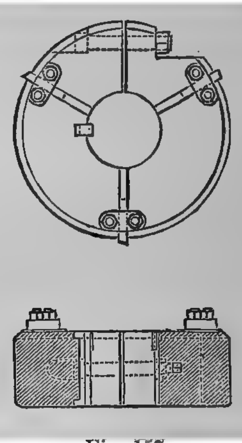


Fig. 157.

be withdrawn from the work by hand or power, and the cutter-head may be similarly fed in at the proper speeds for the heavy rough cut and the finer finishing cut. Facing-rests bolt to the two face-plates so that the sinking head may be cut off and the flanges faced up while the roughing cut is in progress. This arrangement gives truer

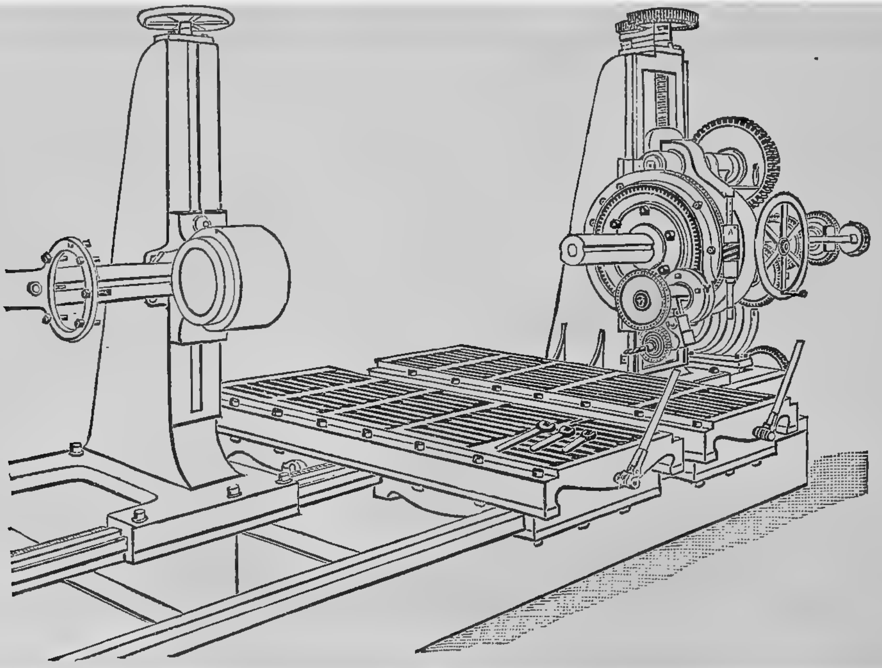


Fig. 158.

work than when the facing-tool is driven from the bar, since the variation in resistance will cause a springing of the joints in the latter case. By this machine the time for boring and facing a locomotive cylinder of usual dimensions has been reduced to a little over one-third of that required with less perfect machines. The boring-head for these bars is made to clip the latter (Fig. 157). The head is cut at one element, and is held by a bolt, which clamps firmly and yet can be instantly released.

A similar tool, designed for large horizontal work, is shown by Fig. 158. Beside boring and facing cylinders of large size, by this machine the holes in the flanges for the cover-studs can be drilled. The whole live-spindle head can be raised and lowered by power, and the post is arranged with a bracket bearing which will support the outer end of bars of different diameters by means of inserted bushings. Its longitudinal and vertical adjustment are effected by screws. The flange-drill E is revolved around the center of the spindle by the worm A′ and held in place by it. By this system the holes can be adjusted to be on the circumference of any circle around the axis of the cylinder and can all be spaced equally.

Fig. 159 shows a third upright with a longitudinal and transverse motion beside the vertical adjustment. This head is used for surfacing work. The tables have compound motion. The bed of this machine is 39 feet long.

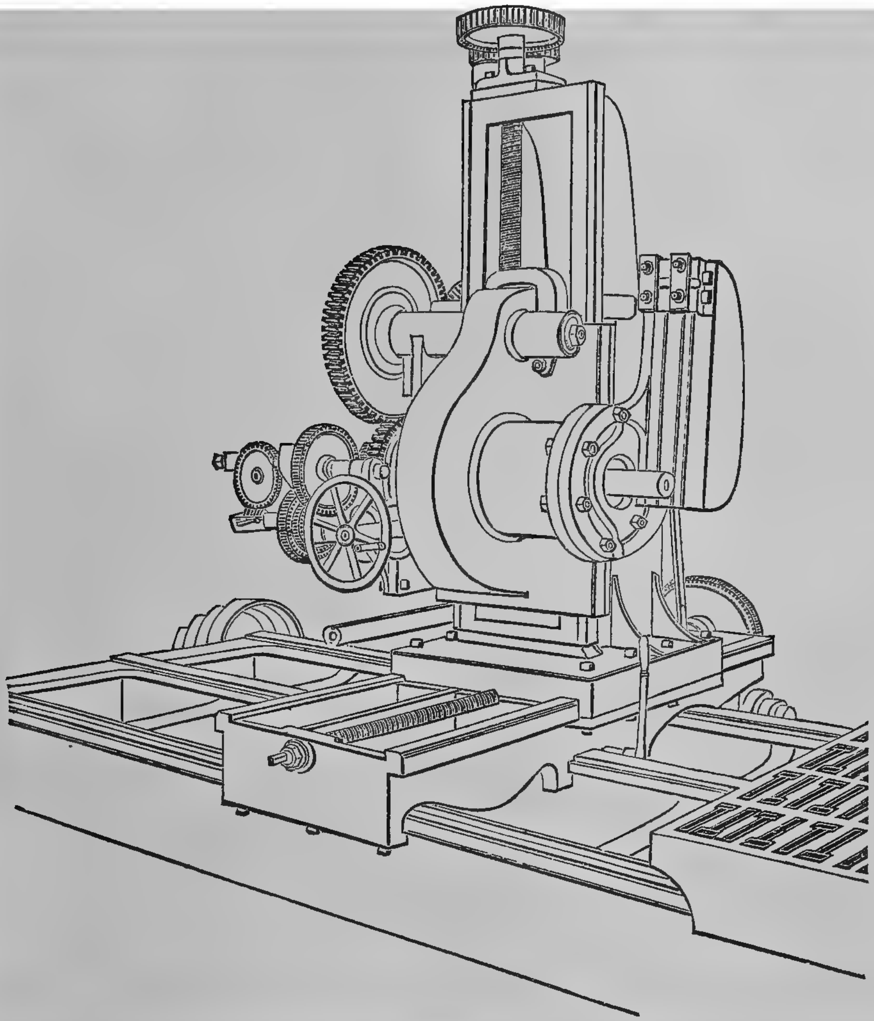


Fig. 159.

§ 20.

DRILLS.

The distinction between drilling-machines and boring machines is not very marked with respect to their function. Usually, however, the drill cuts only at the bottom of a hole in the solid metal, while the boring-tool cuts at the side or bottom of a hole already made. It is possible in the case of most large holes to have them either punched or cored, whence their enlargement to exact size will be effected by boring. Drilling will be usually resorted to for small holes. A drill will, therefore, turn more rapidly than a boring-machine, and will usually be a much lighter and smaller machine.

The question of feeding the drill-point forward against the work was for a long time debated. Some held that it was unwise to have power-feeds; others approved them. Practice of to-day favors a disengageable feed from the spindle, permitting a quick-return by hand, or a hand-feed if desired.

The prevailing drill properly so-called has its spindle vertical. The motion from the horizontal shafting of the shop must, therefore, be transmitted to the spindle through a pair of bevel-gears or else by belt over guide-pulleys. The bevel-gear combination is in the majority. The work will be secured to a T-slotted floor-plate under the spindle, or to a table, according to its size, and according to the type of machine.

The drill-presses may be variously divided, according to their form. For convenience they will be discussed under the heads of upright drills, radial or column drills, and other forms. The latter will include such types as the suspended and multiple drills and special designs.

§ 21.

UPRIGHT DRILLS.

The upright drills (so-called) are usually made to be self-contained. The counter-shaft, with fast-and-loose pulleys and the nest of cone-pulleys, is put at the back of the machine and conveniently near the base. This position of the cone-pulleys makes the shifting of the belt quite easy. The horizontal driving-spindle will be at the top of the machine, both being carried in journals which are on brackets from the main upright of the tool. There are two types of practice with respect to the manner of securing these brackets. Some designers cast the upright and brackets all in one piece. This type is called a "gooseneck" drill, and is illustrated by Figs. 162, 167, and 168. It has the advantage of stiffness and cheapness of fitting. The other type has the brackets bolted to flat seats made for them. By this means is avoided the risk of failure of an entire large casting because of defects of small parts of it.

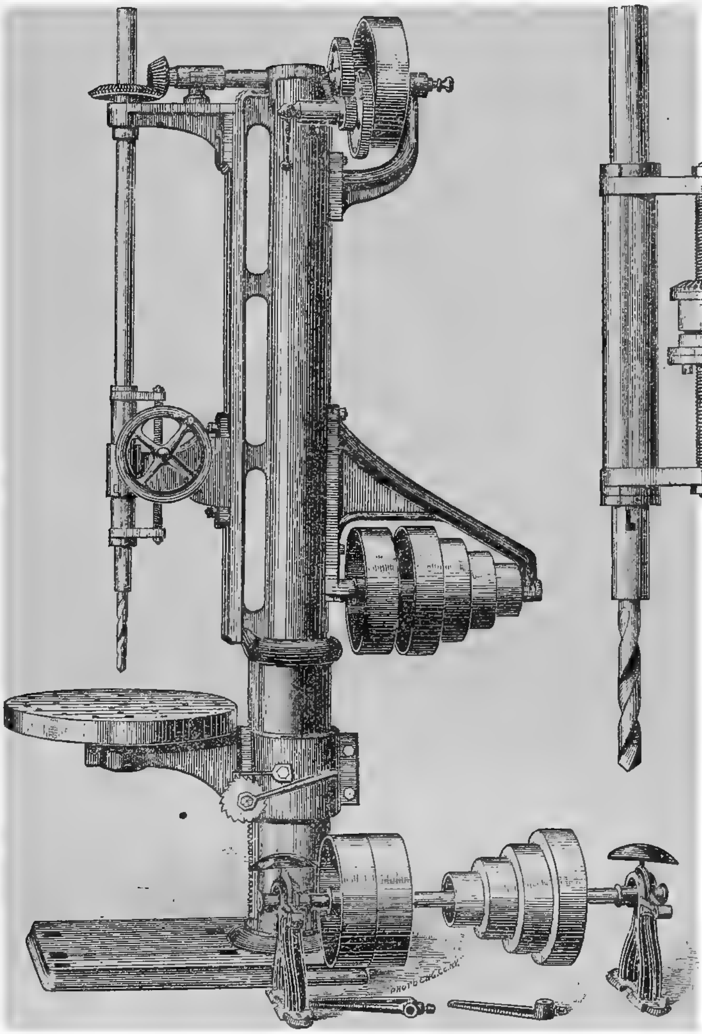


Fig. 160.

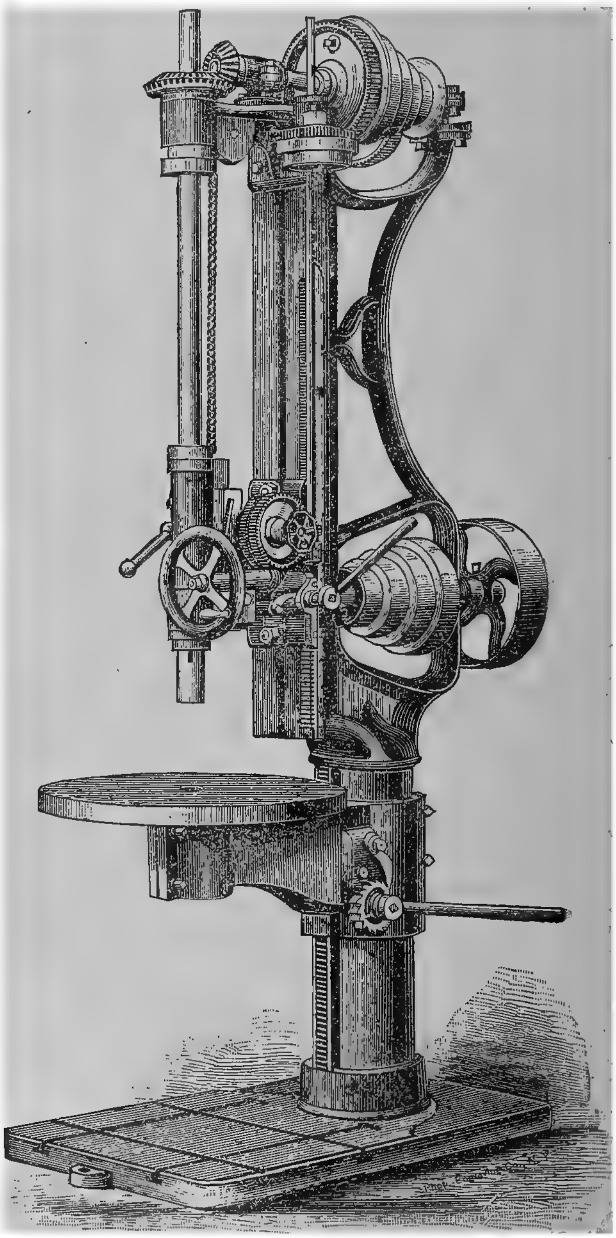


Fig. 161.

A type of this design is shown by Figs. 165 and 170. Upon the lower part of the principal upright a cylindrical surface is turned. Upon this fits a bracket, very usually split so as to clamp in place, which carries the table. This table is made with slots and T-holes in it for securing work, and its top surface must be truly horizontal when the tool is in place. This table is made to raise and lower by a pinion meshing into a rack. This pinion will be turned directly in lighter tools by a crank or ratchet-lever, or indirectly by a worm and wheel. One form uses

a worm (Fig. 167) meshing directly into the rack whose teeth are inclined to conform to the obliquity of the screw. This rack is not cast on the cylinder but fits between collars at top and bottom of the turned surface, and is kept in its vertical position by its fit through the knee. By this expedient, not only is the fitting of the table made more easy, but the table can be made to swing around the upright out of the way of the spindle, if desired.

The foot of the upright rests in a foot-plate in a long, deep socket. In newer practice this foot-plate is planed and slotted to secure deep work to, that it may serve also as a table. The table is usually held in the bracket by

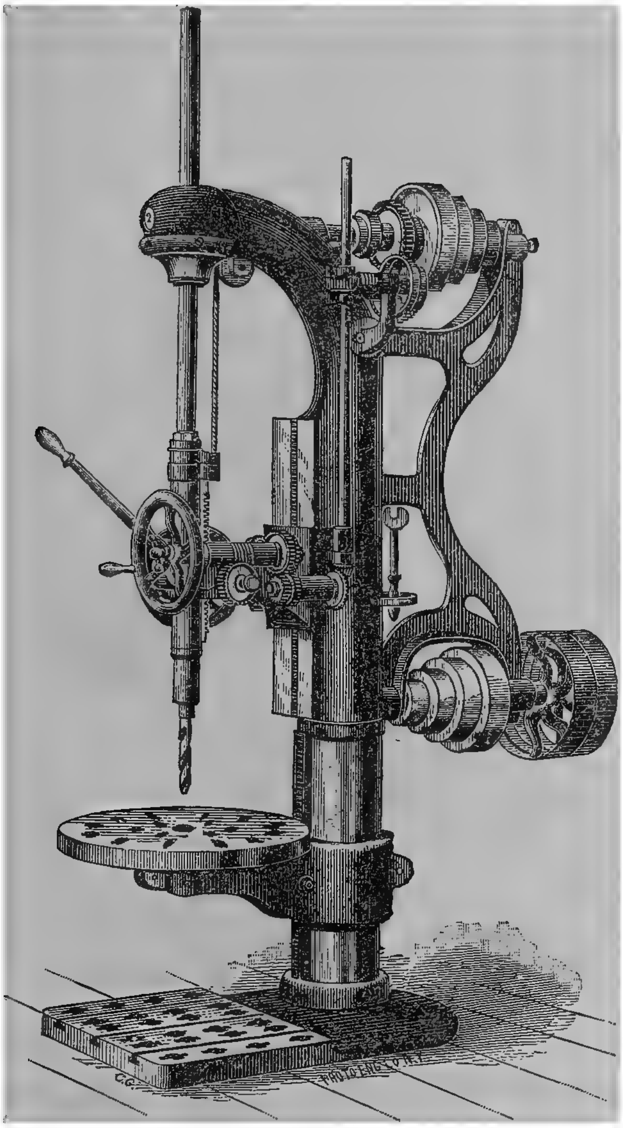


Fig. 162.

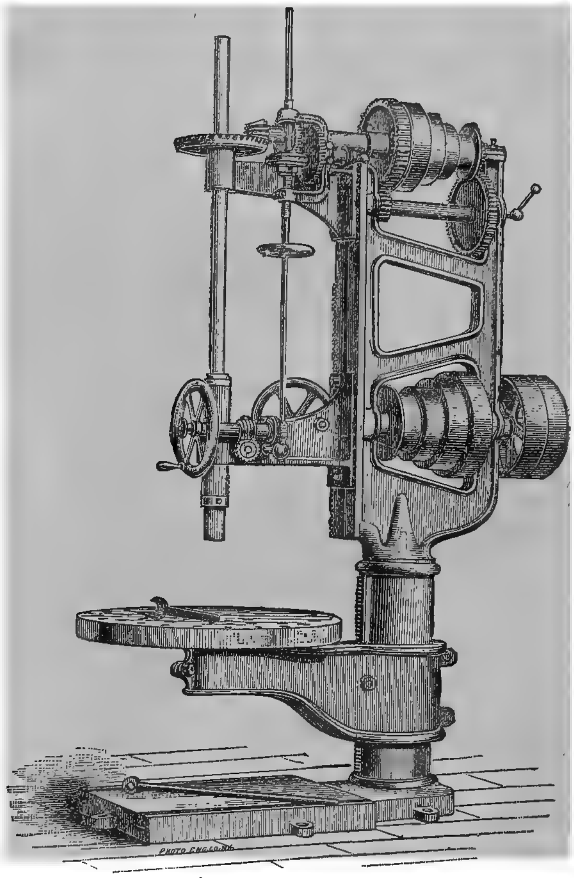


Fig. 163.

a clamp, taking hold upon a cylindrical post, on the lower side central and perpendicular to the finished face. Sometimes this post is screwed into the clamp-nut of the bracket, for finer vertical adjustment. Perpendicular to this table and to the planed foot-plate must turn the spindle of the tool. This is driven from bevel-gear on the upper spindle, the horizontal gear being usually the larger, that the belt-pulleys may turn at high speeds. The horizontal gear usually turns in the bearing in the upper bracket, being provided with a very long hub. This avoids the cutting and wearing of the bearing by the sharp edge of the spline. The vertical spindle must be splined to permit the motion for feed and for adjustment, while the driving bevel-gear remains stationary. The lower bracket, which guides the lower end of the drilling-spindle, is made adjustable vertically for work of differing depths. It is provided with a long knee, which clamps to a planed slide in the front of the tool. Where the bracket is not counter-weighted, the bracket is lifted by a pinion turning in a rack cast in the slide (Fig. 161). The newer types are arranged to move by the unaided hand.

Fig. 160 illustrates one of the older types with separate counter-shaft and hand-feed only. The feed was by a screw bracketed out from a sleeve through which the spindle passed. The sleeve only is fitted to the bearing in the bracket. At the bottom of the sleeve is the point at which the thrust of the cut is borne. Present practice

puts a brass washer, or a hardened steel washer, or a washer of rawhide at this point, and any lost motion or wear is taken up by different devices above the sleeve. In place of the screw, the practice of to-day favors a rack, usually cast as part of the sleeve and fed downward by a pinion, driven through worms.

Fig. 161 shows the rack and ratchet device for lifting the feed-bracket. This is made necessary by the fact that the spindle only is counter-weighted. It is of course more important to counter-weight the spindle in order that its weight may not be released suddenly if the drill-point enters a blow-hole. The edges would be likely to catch,

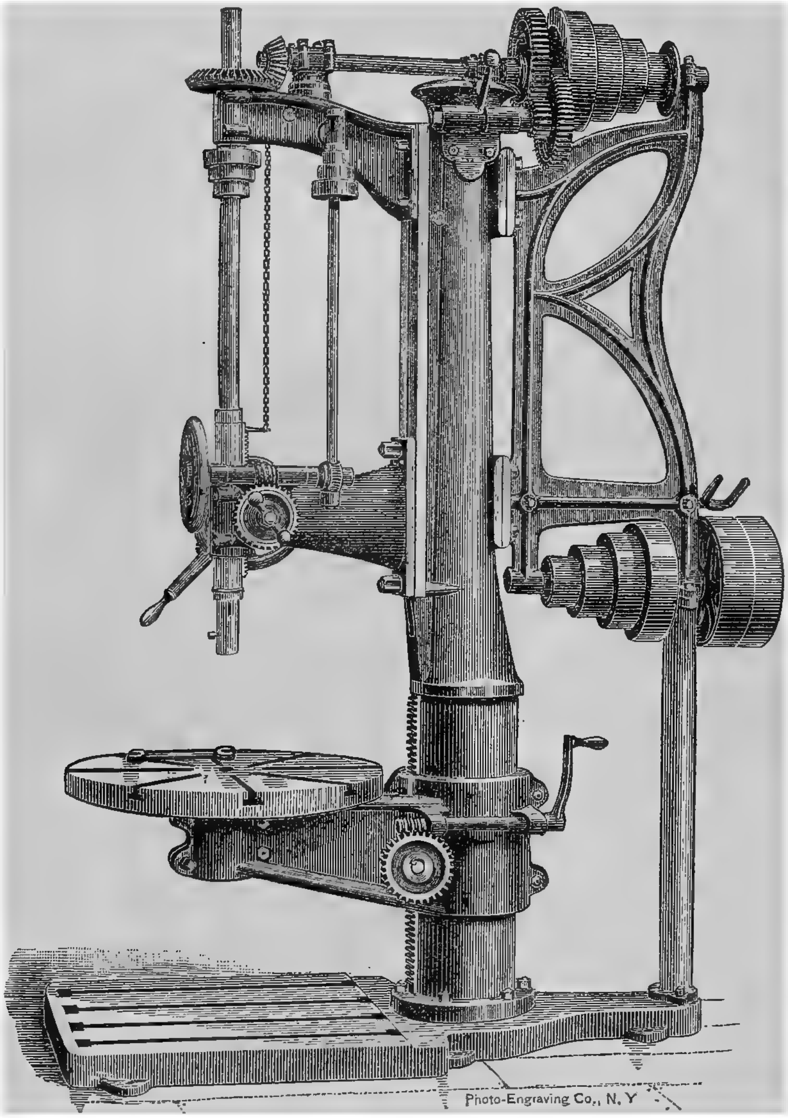


Fig. 164.

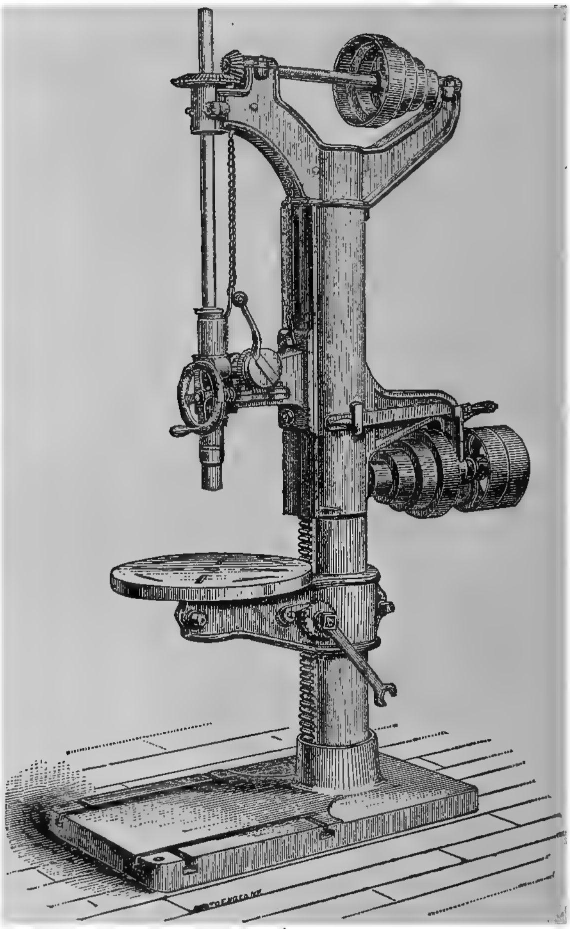


Fig. 165.

and the drill would break. The power-feed is from cone-pulleys on the hub of the horizontal driven bevel-wheel, which drive a splined worm-shaft by reducing gear. Hand-feed through a second worm is disengaged by friction, and a quick-return lever, for use when both are thrown out, is on the farther side.

Fig. 162 shows the typical gooseneck drill. The counter-shaft is on the back of the tool, and the bevel-gears are incased from dust. The feed changes are made without shifting the feed-belts by shifting-splines on the movable bracket spindles. The hand-feed and quick return are engaged by friction. The counter-weight hangs in the column.

Fig. 163 shows a drill of 48 inches swing, fitted with a variable power-feed by a brush-wheel combination. The power is gained by two worms. The hand-feed is disengaged by friction.

Fig. 164 shows a counterpoised spindle design. The rear post is introduced to stiffen the frame against the thrust of the cut. This flexure of the upright is one of the great defects in the single upright system. The same drill illustrates the lifting of the table by worm-gear.

Figs. 165 and 166 show a counterpoised drill in which the quick return and hand-feed are original. The bent lever swings on a pivot in the diameter of the disk, and a tooth on the end of the rectangular part may catch in notches in the face of the worm-wheel. The power-feed may be disengaged by a friction-clutch.

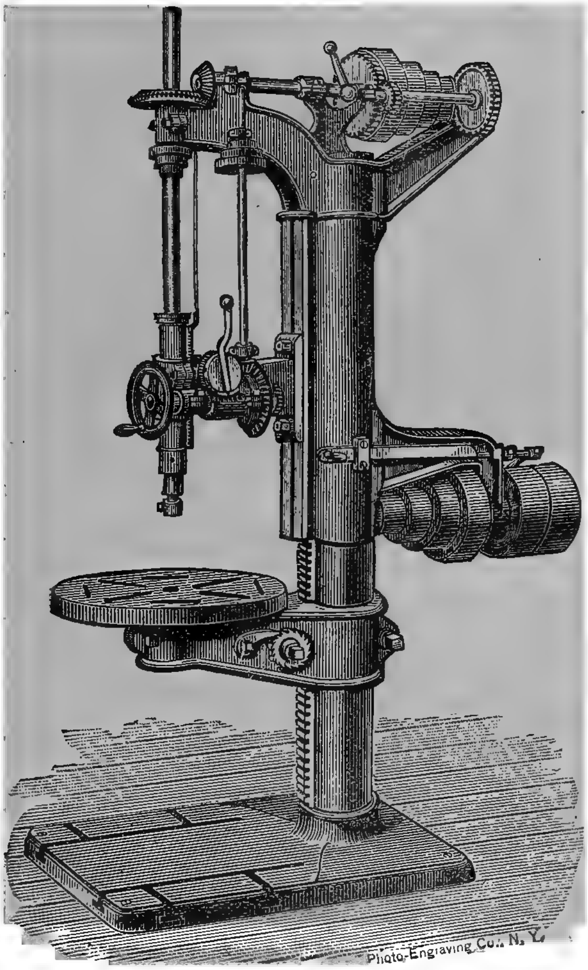


Fig. 166.

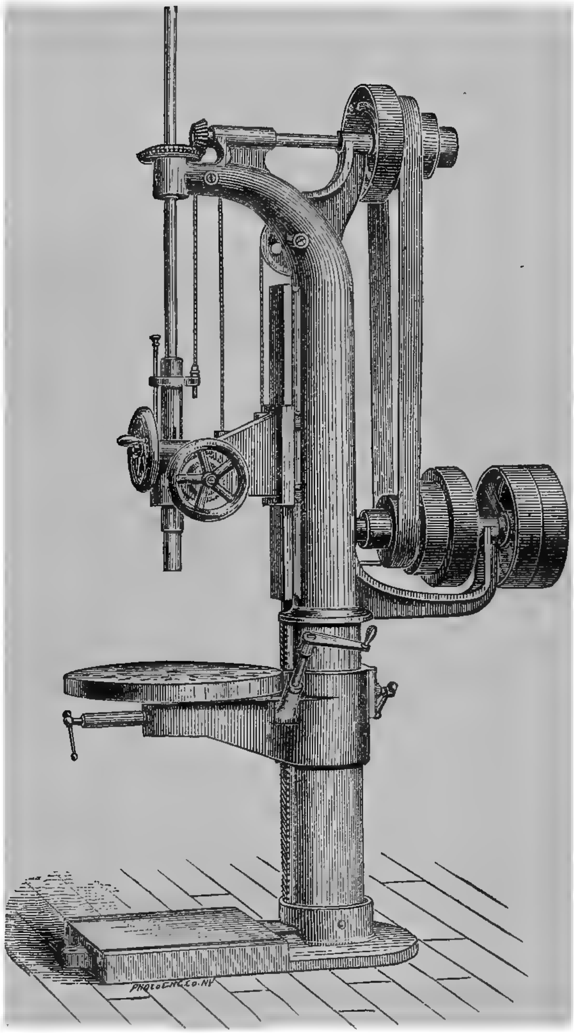


Fig. 167.

Fig. 167 uses but one weight to counterpoise both spindle and bracket. The wire rope is continuous, and passes under a sheave in the bracket from over pulleys in the upright. There is also an adjustable depth-gauge attached to the lower stock. This is an accurately graduated scale, which enables the operator to determine the penetration of the drill by an index on the feeding-sleeve.

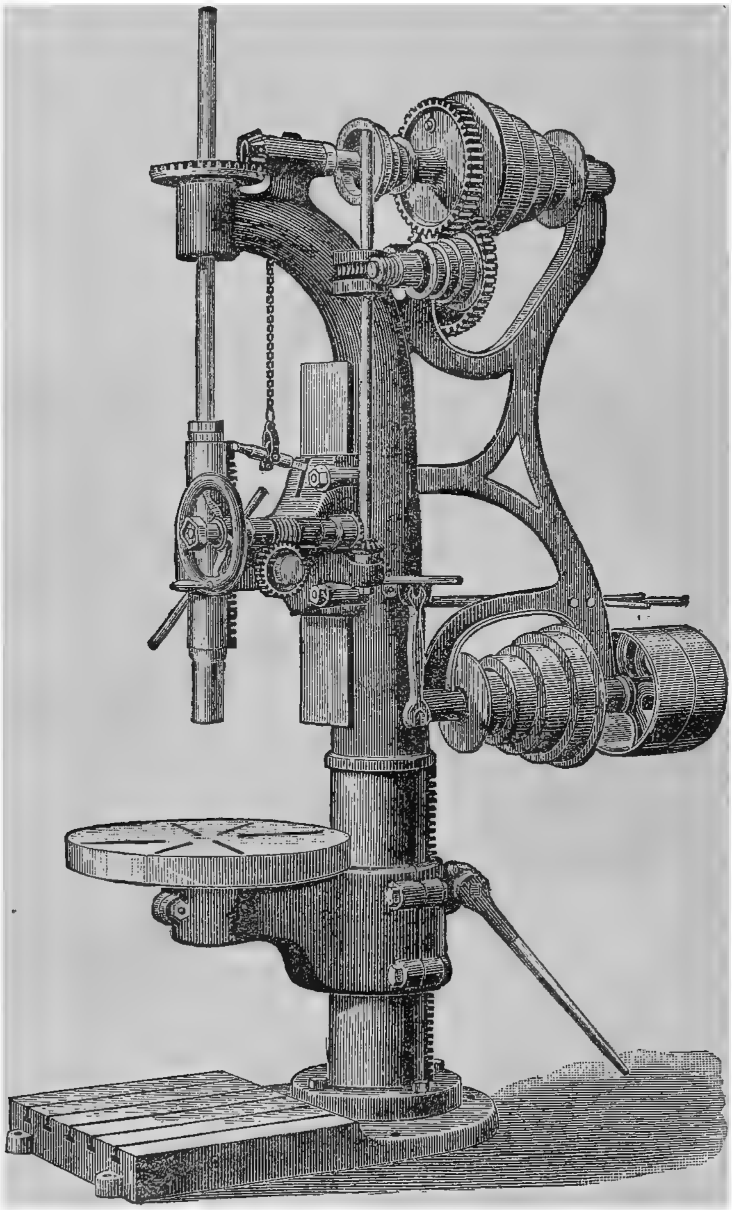


Fig. 168.

Fig. 168 shows a New England design where one weight counterpoises both spindle and bracket. The chain lifts both by a hinged lever, attached to the bracket near its center of gravity by a link. This link compensates for the motion of the spindle, and the adjustable clamp of the clevis D permits any proportion of the counter-weight to be distributed upon the spindle joint as the weight may vary in the socket. The power-feed and quick-return are controlled by friction-clutches. This tool also illustrates the compacting of the back-gear mechanism upon a short axis. This is very general in the newer tools.

Fig. 169 illustrates the same arrangement of back-gear, but the spindle has but one long bearing instead of two. The table has a very long vertical adjustment by a screw let into a slot in the column. The brass nut of the screw can be disengaged by the pin below the table in front, so that the table may swing aside. The changes of feed are accomplished by the three bevel-gears on the worm-shaft. The vertical gears are engaged with the geared spindle by a movable spline operated by the rod and milled head at the rear end. The counterpoise is annular over the top of the spindle-cap.

Fig. 170, by the same builder, illustrates the bolted system for the upper brackets.

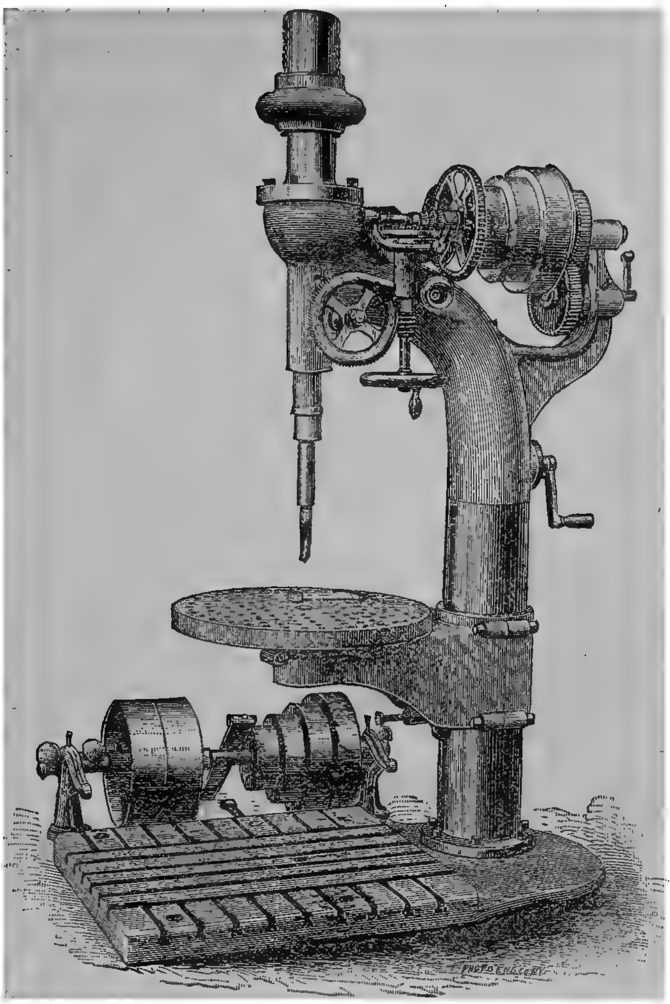


Fig. 169.

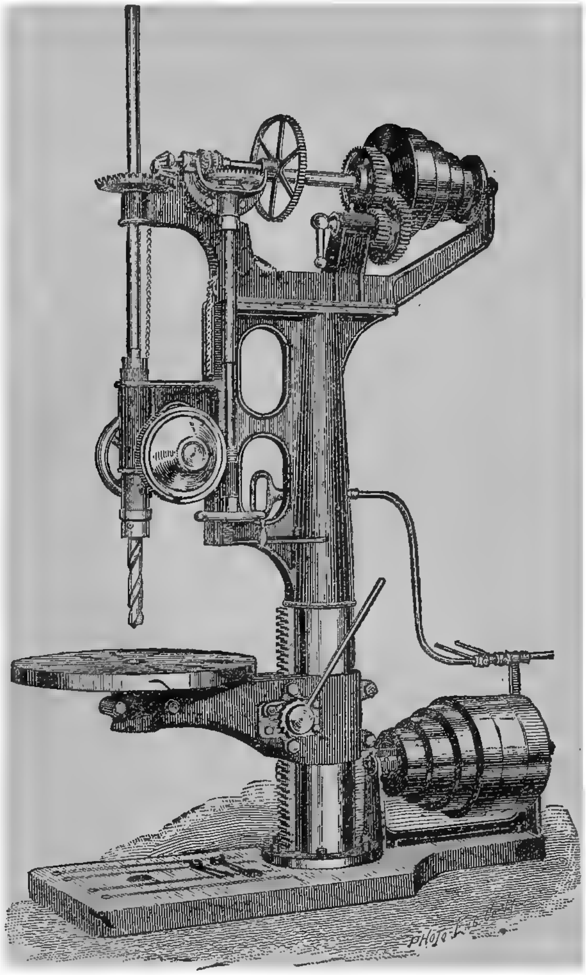


Fig. 170.

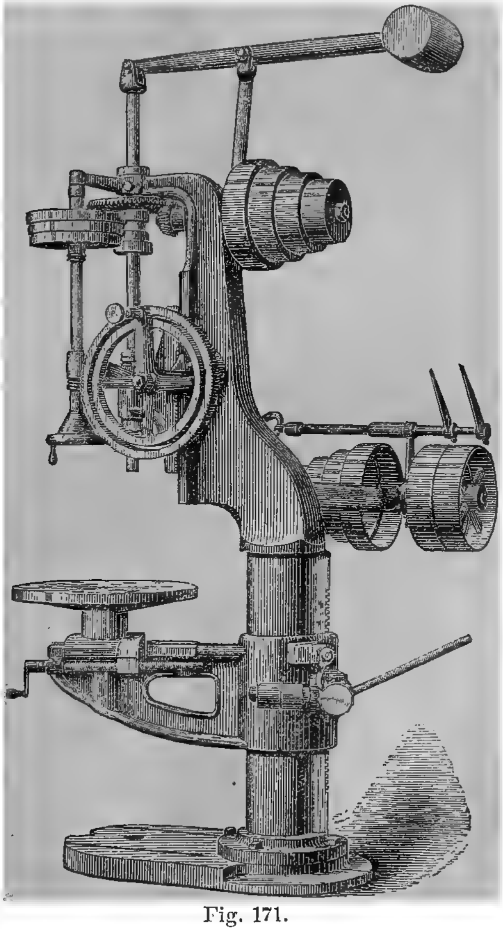


Fig. 171.

Fig. 171 shows a lever counter-weight drill, with the feed driven by a cone of belt-wheels. The hand-feed and quick-return device is by a frictional clip in the sunk ring of the worm-wheel. The handle of the crank forms a screw-clutch. The table has a horizontal traverse by screw.

Fig. 172 shows a lever counterpoise drill, the links being curved so that the short lever may not cause binding upon the spindle. The quick-return is by a lever on the left-hand side, the worm of the feed-motion being moved laterally away from the pinion wheel by an eccentric on the vertical rod at the right. The power-feed has three

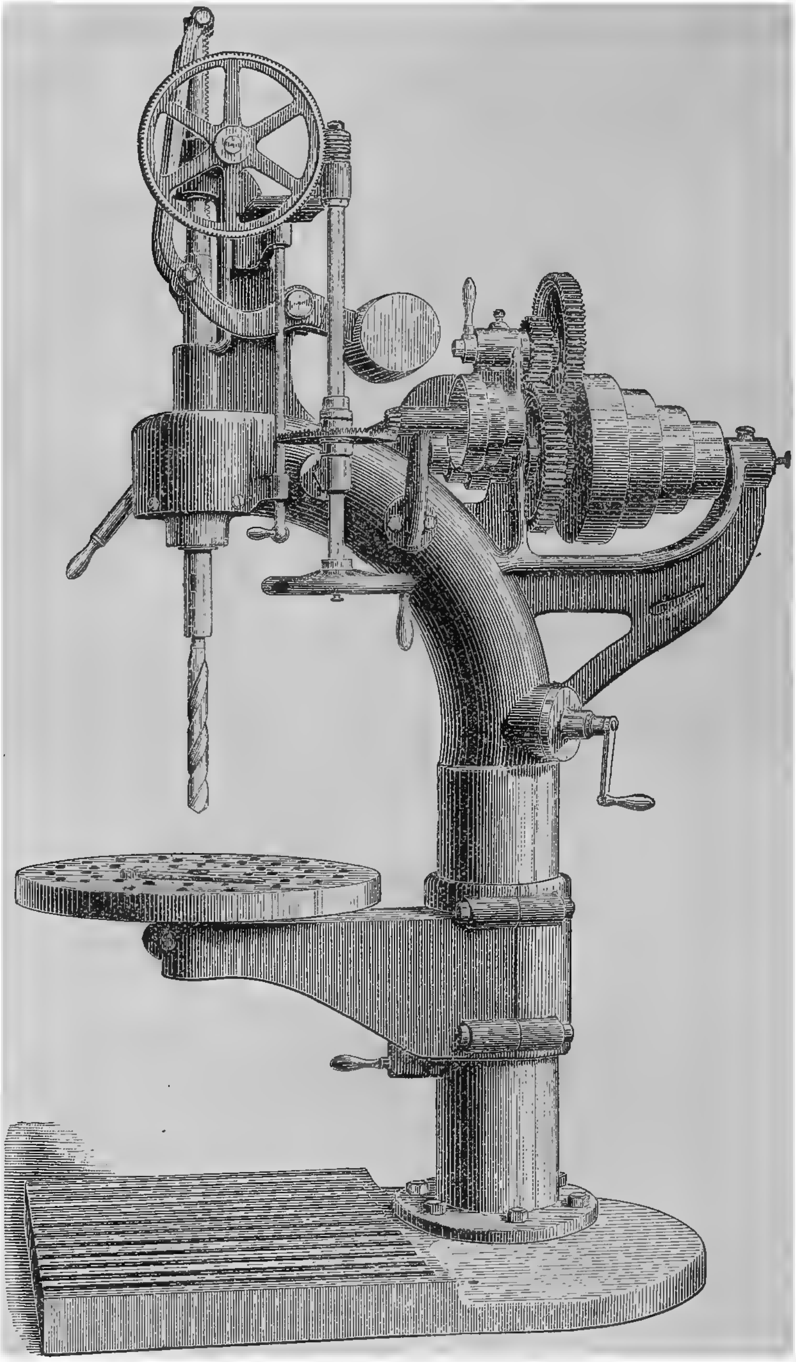


Fig. 172.

changes by a belt cone, the horizontal gear being disengaged for hand-feed by a jaw-clutch. This is lifted by the rod, in the axis of the worm-shaft, by the milled button below.

Fig. 173 illustrates a type of drill in which the spindle may be driven by belt only, when the back-gearing is not required. The belt passes over guide-pulleys, on the back of the square upright. The direct use of a belt gives a smoother running for very small drills. The feed is by a screw of steep pitch engaged by a clutch worked by the latch-lever. The thrust is borne on the very long nut of the feed-screw. The table is gibbed to a flat slide in front of the upright, but by loosening two bolts the table is released and swings to one side. The axis of the swinging of the table is the lifting-screw, which is at the left side, and is turned by power. The power for this motion of

the table is obtained by clutching a horizontal internal shaft with bevel-gears. The clutch is worked by the lever near the base of the upright, and access to the gears is had through the small door. The table has screw traverse in both directions, which is often found a great convenience in miscellaneous or spaced work.

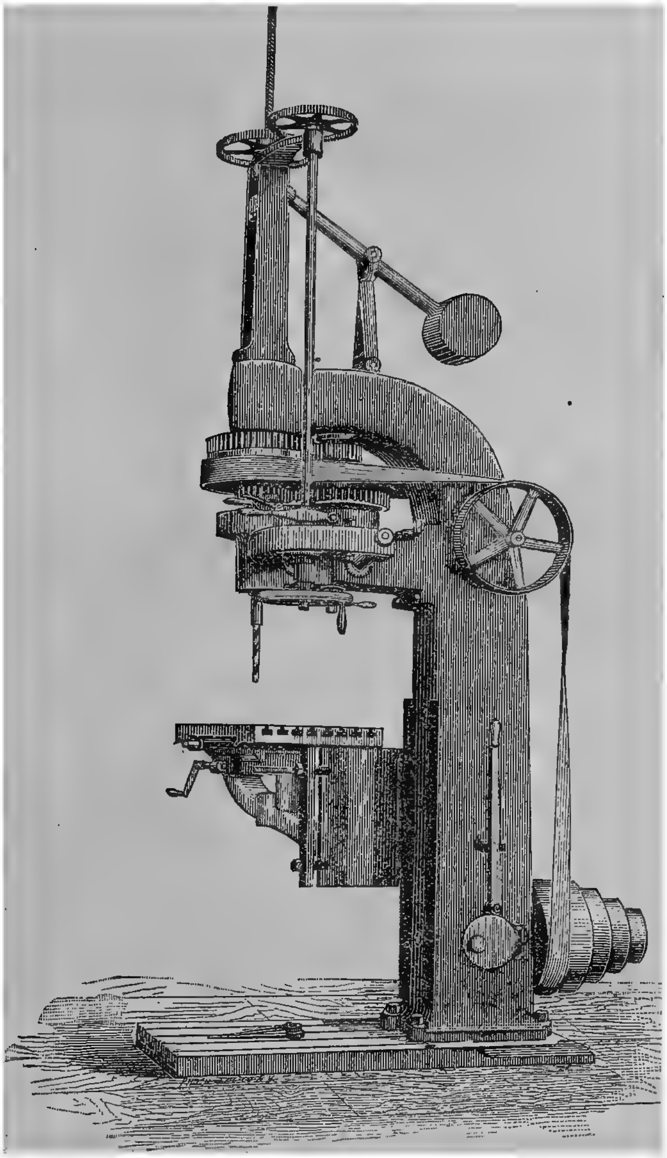


Fig. 173.

§ 22.

RADIAL OR COLUMN DRILLS.

This class includes those in which the carriage bearing the drilling-spindle is adjustable upon a horizontal arm, which swings cranewise around a vertical column. The drill-point can therefore command any point in an annular area, determined by the outer and inner swing of the radial arm around the center of the column. A tool of this sort is especially adapted for heavy work, inasmuch as the drill can be moved to any point of the work more easily than the work can be adjusted under the point of the drill. Moreover, the swinging of the radius permits the drill to command a variety of tables of different levels.

Such a tool is illustrated by Fig. 174. The radius arm is double, to give firm bearing on both sides of it for the spindle-carriage, and has a long internal bearing from the collars upward. The radius is clamped in place by the split in the sleeve at the collars. There is a slotted floor-plate, a tilting-table, adjustable by a screw and clamp, and on a third side may be a pit, if desired, to work on the ends of very long pieces. The tilting-table permits the drilling of angular holes, and is preferred by the builders to the use of an inclined spindle. The tool is driven by a central vertical shaft from a cone-pulley shaft below. A splined shaft takes off the power in any direction from the bevel-gear on the top. The carriage travels over the radius by a rack and pinion from the hand-wheels, and the

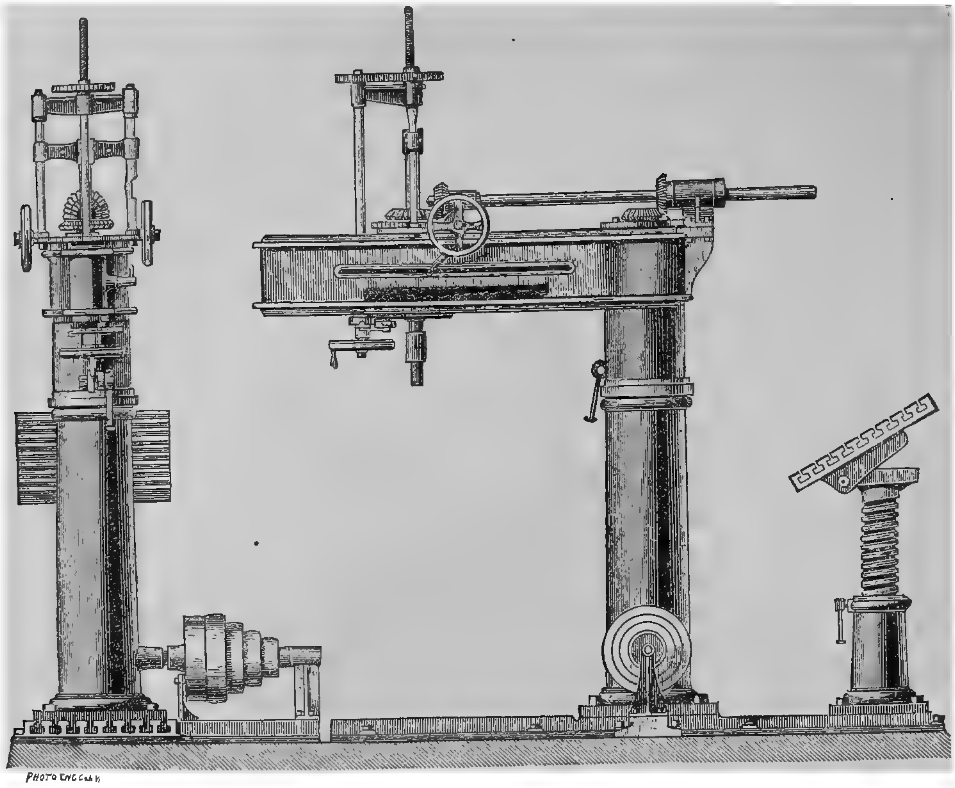


Fig. 174.

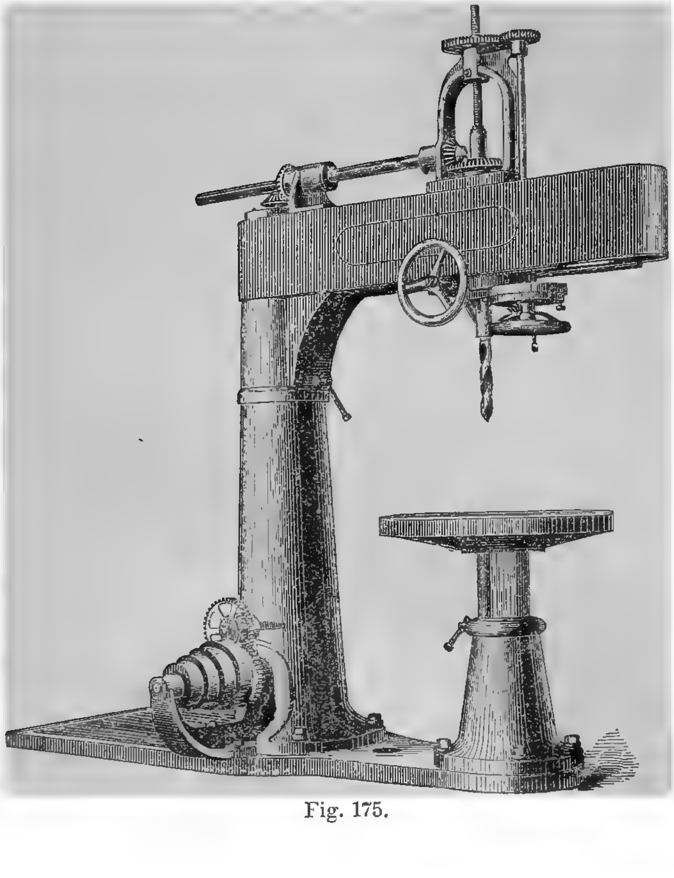


Fig. 175.

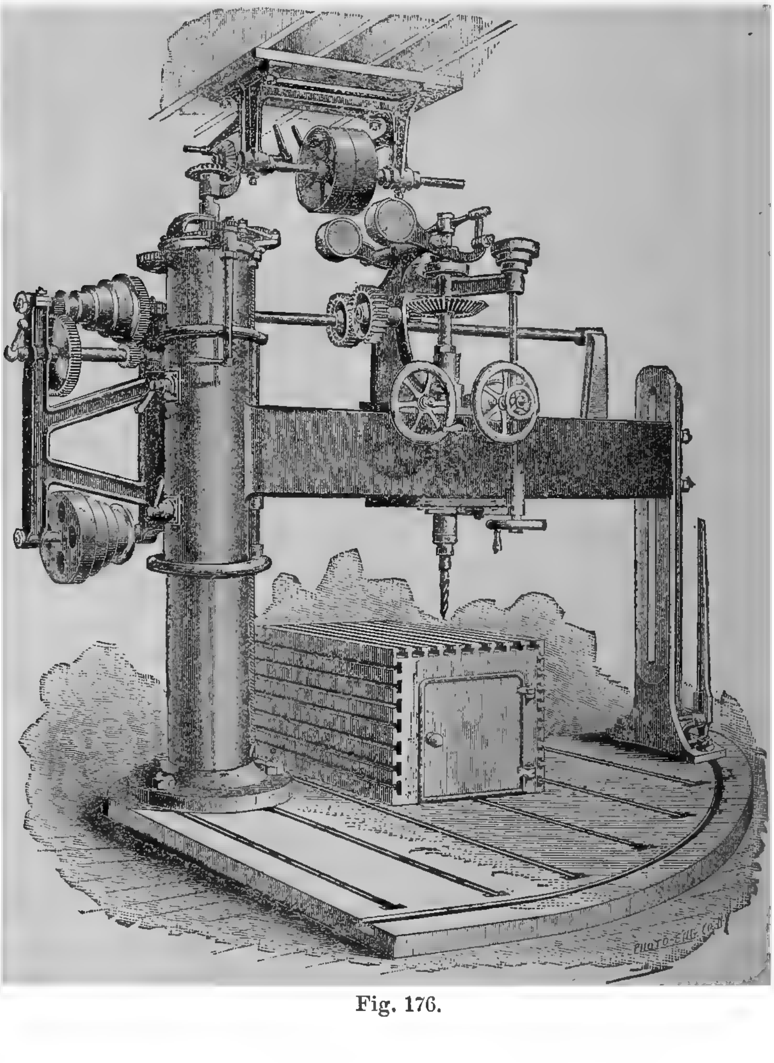


Fig. 176.

tool is fed downward by a screw. The back-gear connection is very compact. Fast to the large pulley of the cone is a small gear. This meshes into a second whose stud is carried by an arm fast to the spindle. This arm is counterpoised on the other side of the spindle, and by this sector the arm can be locked to an internal wheel with which the idle gear is always engaged. When so locked the spindle will turn with the cone. When the internal wheel is locked to the base-plate of the drill and the sector is released, the arm will be carried around as the idle-wheel rolls on the internal wheel, and the speed will be much reduced.

Fig. 175 illustrates a very similar design.

Fig. 176 shows a design intended to increase the vertical capacity of the tool, by making the whole radius move vertically upon the column. This enables the tool to act easily upon very flat, heavy work. The lifting-screw is driven by power from the central shaft, engaged by the lever motion from the handled rod. This tool also avoids a difficulty which results from the overhang of the radius when heavy cuts are made. A slotted post, moving on the arc of the end of the radius, may bolt the latter to the bed, when the tool becomes as rigid as could be desired. The spindle is driven by a pair of gears from the splined shaft, which may be driven directly or double geared. The feed is from cone-pulleys to a worm and wheel, disengaged by friction for hand-feed.

Fig. 177 shows a similar design, where the drilling-spindle is universal, and holes may be drilled at any angle. The spindle is driven from the splined shaft, below the radius, by two pairs of bevel-gears, the axis of the idle pair being in the center of the swivel clamp-plate. The tool is driven directly from a horizontal belt, and the arm is

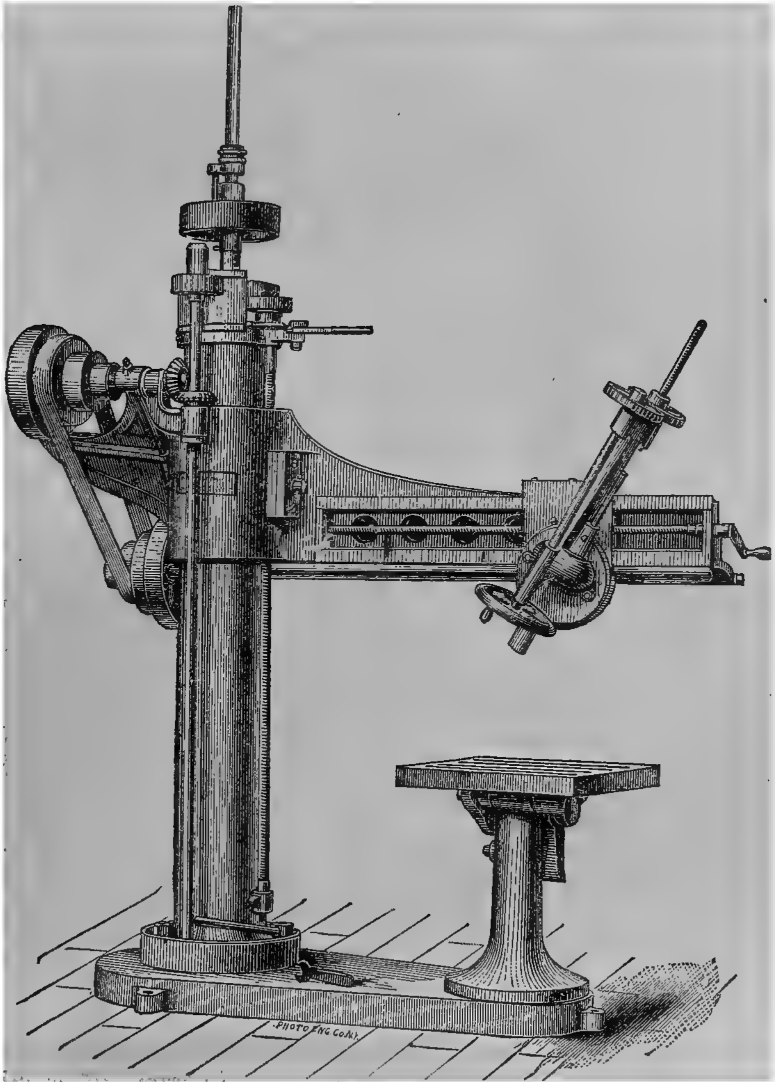


Fig. 177.

raised and lowered by power. In all the tools with this feature the column is a finished shell which turns upon an internal post with a long bearing. The shell is clamped in place by the bolts in the flange at its foot. It will be seen that by the two motions of this tool, a hole may be drilled in any direction and at any angle with the horizontal plane. The radius can bring the spindle into any vertical plane, and the swivel-plate permits the drill to be presented at any angle in that plane. Horizontal holes can be drilled in work of any length, the work lying on the floor or on trestles. Holes may be bored in erected locomotive-frames by using a long false socket.

Fig. 178 shows the spindle mechanism of Fig. 172 applied to a radial drill, and Fig. 179 shows a universal drill by the same builders. The radius slides on a faced slide, and the shell of the upright need not be finished all over. The raising and lowering is by power, the gears being engaged by the handled lever on the upright. The feed is by a screw, and may be made automatic with three changes, also as well as by hand.

Fig. 180 illustrates a belt-driven radial drill. The arm swings cranewise around a splined shaft through a little more than 180°. The guiding-slide is made very long for stiffness, so long as to need no clamping in place

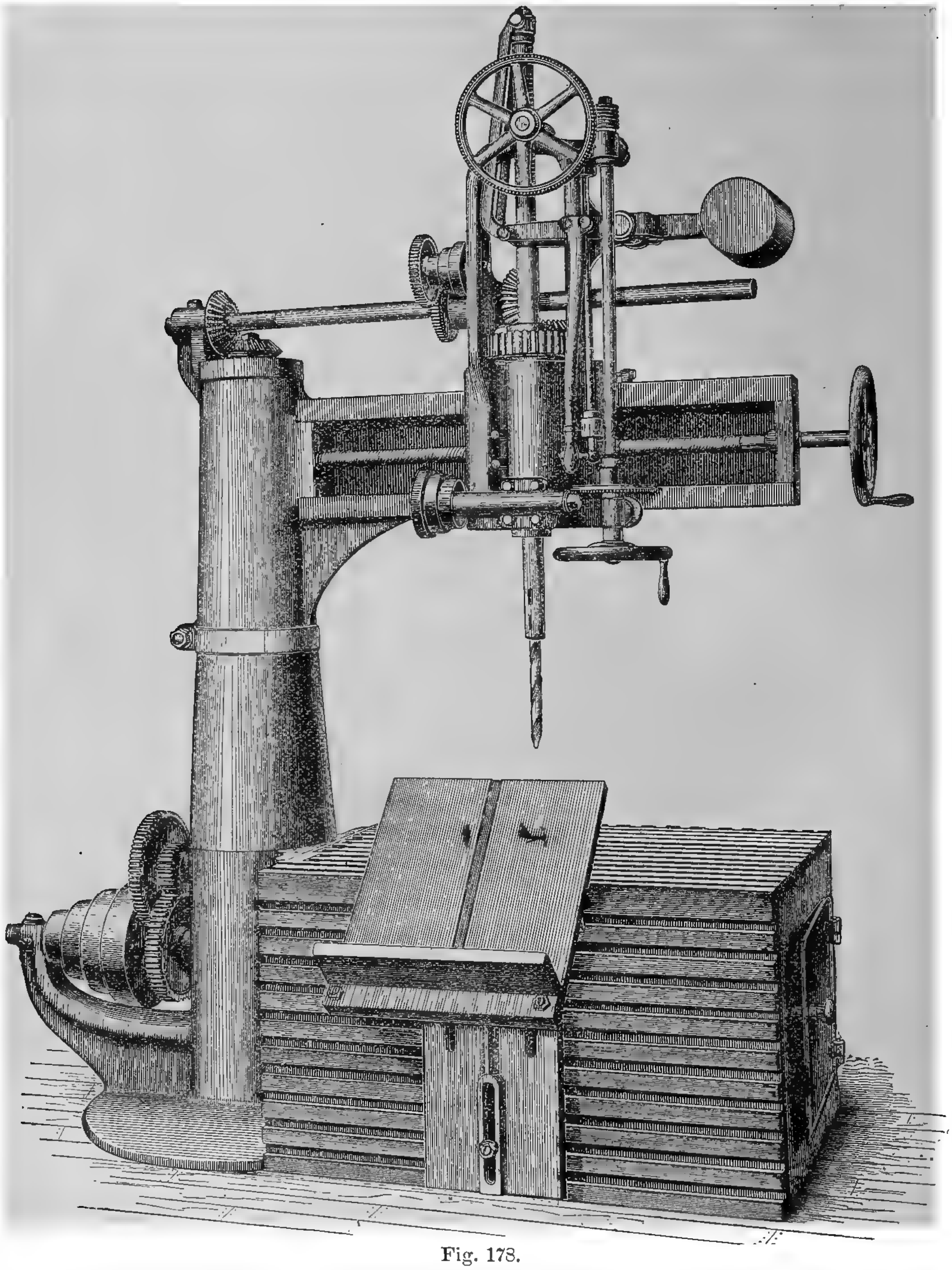


Fig. 178.

under a heavy cut. The arm is raised and lowered by power from the lower shaft. The feed is by a screw-gear, and the carriage traverses by a worm on a diagonal shaft taking into a rack. This cut and several of the others illustrate a form of table which has many advantages. Work may be secured to either top or side, and the interior may be used as a tool closet.

Fig. 181 illustrated a similar adjustable double-faced table for a vertical radial drill. The spindle is carried at the lower end in a bearing on a slide, which is guided and receives the downward feed. The spindle itself, therefore, does not overhang its supports so far when fed out. The feed is by cone-pulleys from the spindle, with an axial spline device for altering or disengaging the power-feed. This has been utilized in an appliance for gauging

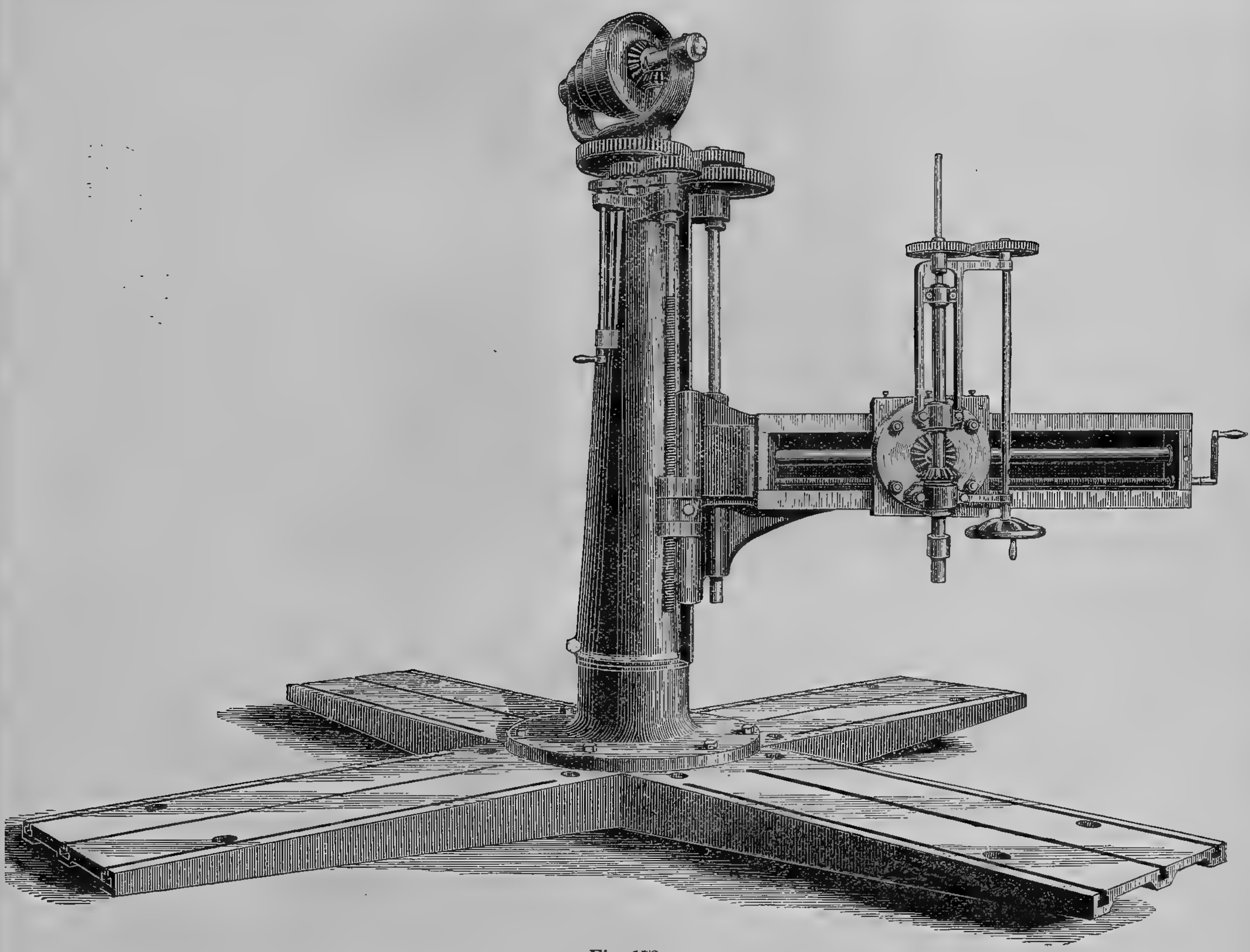


Fig. 179.

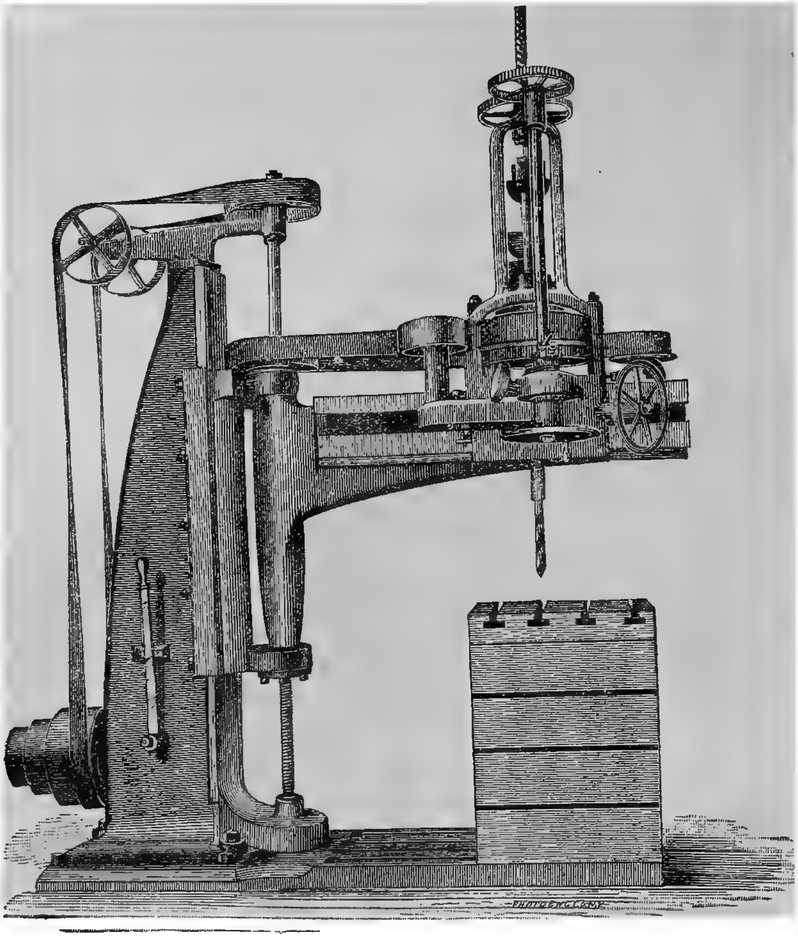


Fig. 180.

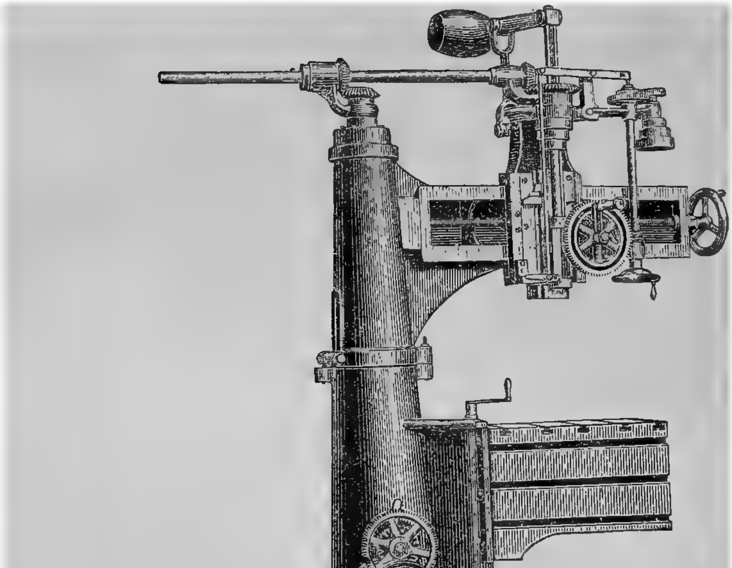


Fig. 181.

and tripping the feed for holes of uniform depth. The spline-rod is attached to a horizontal lever. A dog on the slide strikes a tripping-lever and disengages the feed-spline when the depth has been reached for which it was set. The hand-feed is engaged with the power worm-wheel by an annular friction-clutch.

Fig. 182 illustrates an improved universal radial drill, where all the motions are by power. The crane may revolve around the stump and rise and fall, and the feeds are by power. The jib may also turn around its own axis for oblique work, and the spindle may swivel to any angle. The engagement of the power motions is by hollow shafts and splines.

Belonging to the class of radial drills is the portable drill illustrated by Fig. 183. A short hollow post carries the column of the drill, which can thereby swivel to any radius by worm-wheel and tangent-screw. A long slide feeds the point of the drill in and out on the radius. The spindle-frame is held in a spherical clamp on a ball surface, by which the spindle can be set to drill at any angle up to 30° in any plane. A second sleeve,

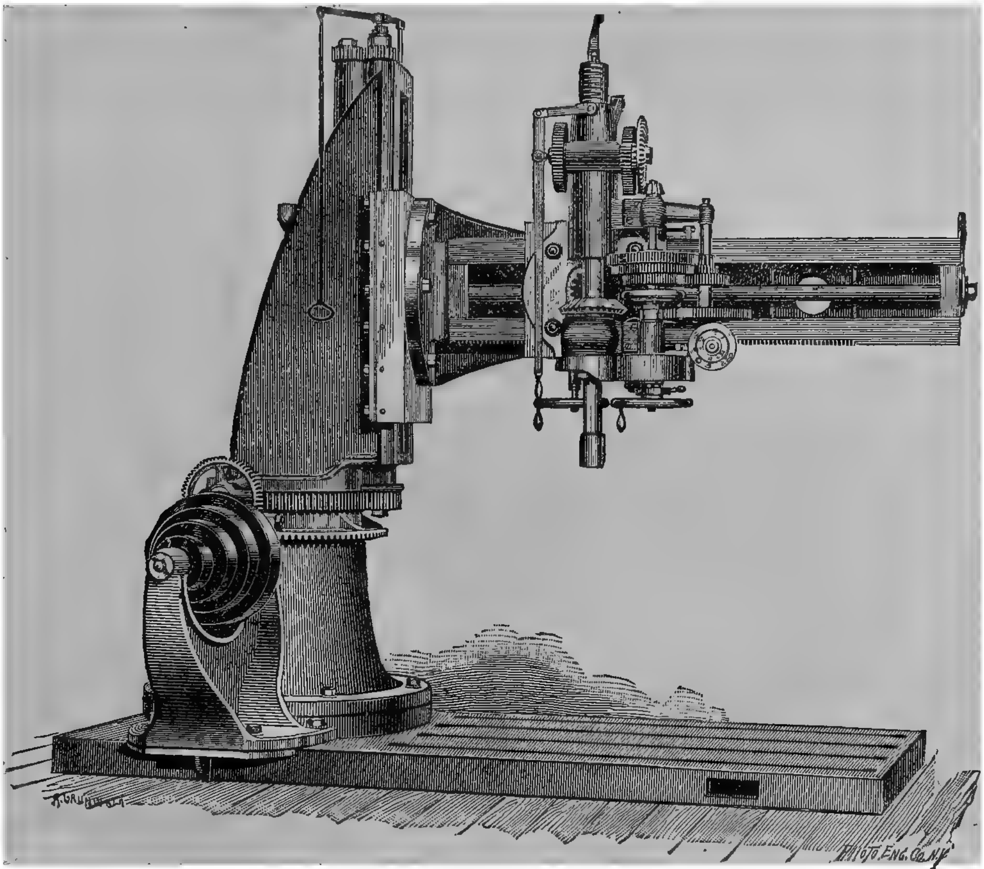


Fig. 182.

on the hollow post, will take the short column horizontally and give the same latitude of motions from horizontal plane. Power is transmitted to a cone of grooved pulleys by a round rope of Italian hemp, which passes over a guide-pulley at the counter-shaft and under another which is free and weighted to maintain the tension on the rope. The overhead guide-pulley is swiveled so that its periphery is always in the plane through the center of the driver in whatever direction the drill may be or at whatever angle. The entire adjustability of the drill in any position over a large area to drill at nearly any angle peculiarly fits this tool for erecting large work. The drill can more easily be brought to the work than the work can be presented to the drill. Of a very similar type of construction are the drills and boring-machines intended for the erecting shop, which are driven from counter-shafts upon the walls of the shop through rods with universal joints. A universal joint at the counter-shaft and another at the tool are connected together by telescopic shafts made of gas-pipe, with collars and set-screws. The two joints neutralize each other's irregularity. Even better than this is the similar use of flexible shafting. Coils of wire wound alternately into spirals, right-handed and left-handed, will transmit the power from a counter-shaft at any angle, and the necessity for supporting the shaft is entirely avoided. This must be done with the telescopic jointed system.

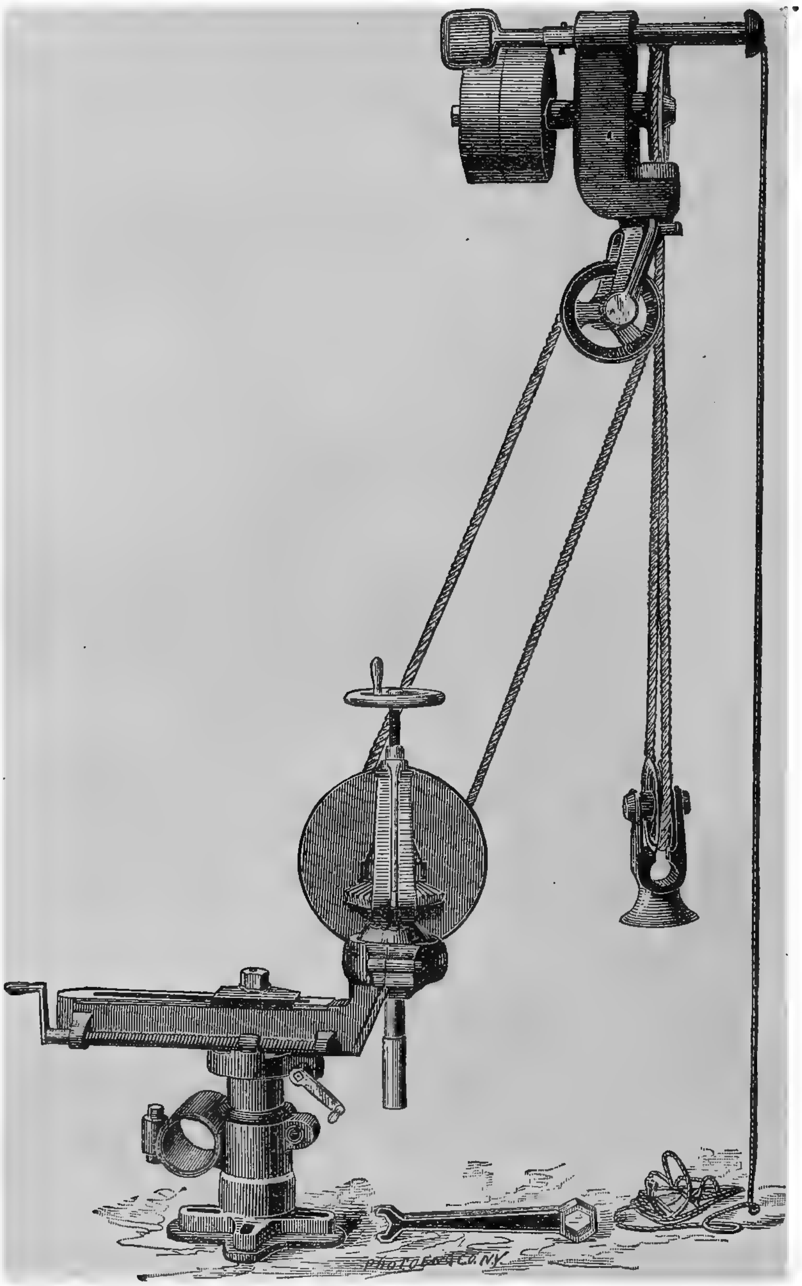


Fig. 183.

§ 23.

SPECIAL FORMS.

Fig. 184 illustrates a form of drill especially designed for drilling and boring the holes for the pins in the eyes of bridge-links. To insure accuracy in length it is wise to bore both holes at once, so that all may be alike. The heads slide upon a bed, and are arranged right and left. The links enter under one head and pass out through the other. Horizontal driving-belts pass from the drums over guide-pulleys to the driving-shaft. When the two heads are upon a wrought-iron screw for adjustment in length of the links, any changes of temperature will affect the link and screw equally, and the heads will slide on the cast iron to keep the lengths of all links the same. In other forms of this tool the spindles are carried on a cross-rail, receiving separate motion and feed from splined shafts geared to cone-pulleys. A primary advantage of this double system is that, by holding the work between centers, two holes may be drilled exactly parallel to each other and perpendicular to the axis of the work; or by putting bushings in the table, such a machine may be used for parallel boring, as in finishing the brasses of connecting-rods when keyed up in the stub.

Fig. 185 shows a machine for drilling the holes for crank-pins in the driving-wheels of locomotive engines. These holes need to be on radii at exactly 90° on the two sides. While the wheels are held by shoes upon their

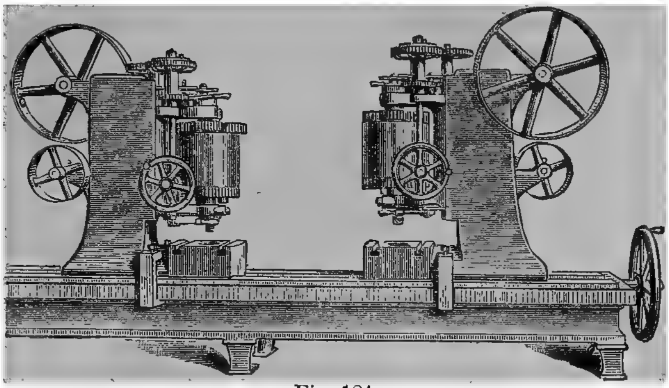


Fig. 184.

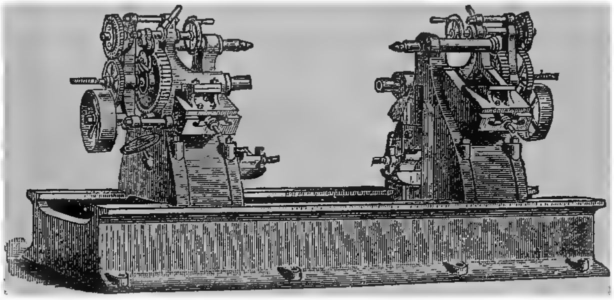


Fig. 185.

tread, and so adjusted as to bring the axle in line with the centers of the machine, the two drilling-spindles move on ways which are in planes at right angles to each other, and can be set for any radius of crank from 5 to 13 inches. The feed of the spindle is automatic, and variable within wide limits.

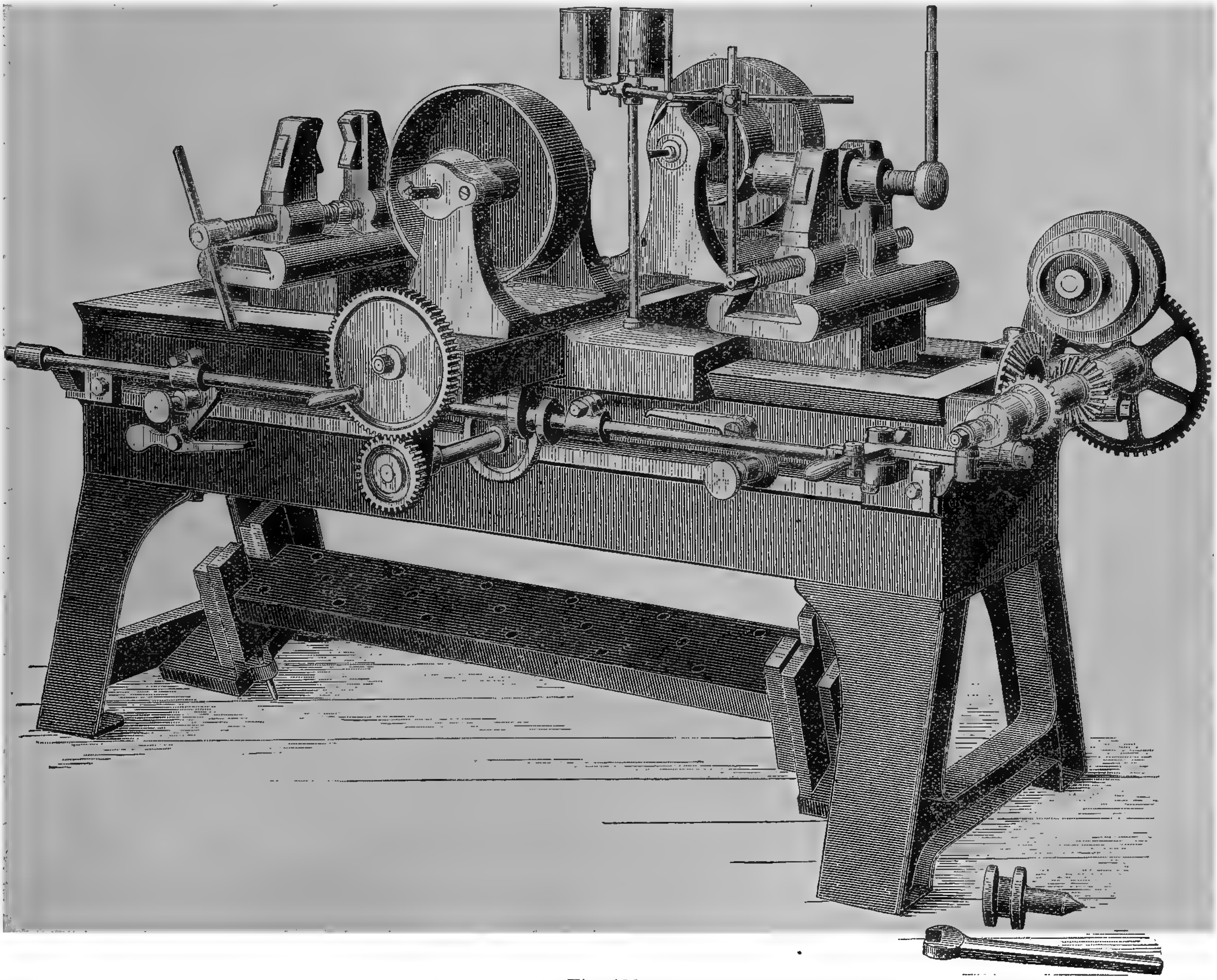


Fig. 186.

Fig. 186 shows a machine for drilling and mortising the seats for keys and cotters. Each drill has a longitudinal traverse of 36 inches and a transverse adjustment and feed of 10 inches. The feed is self-operating in all directions, self-reversing by the clutch and bevel-gears on the shaft at the right head, and the depth of the slot may be limited by a stop. The jaws are self-centering by right-and-left screw, and have capacity for a 7-inch shaft.

Fig. 187 shows a machine specially adapted for drilling the holes for the set-screws of pulleys without piercing the face. The drill is driven by a train of gears incased in the projecting arm, and the pulley is held upon the adjustable mandrel below. The machine has a capacity for pulleys from 56 inches in diameter down to 12 inches, and can also be used to tap the holes for the screws. The different speeds for drilling and tapping are obtained by the two belt-pulleys, and the motion of the tap is reversed by the clutch-lever in the head.

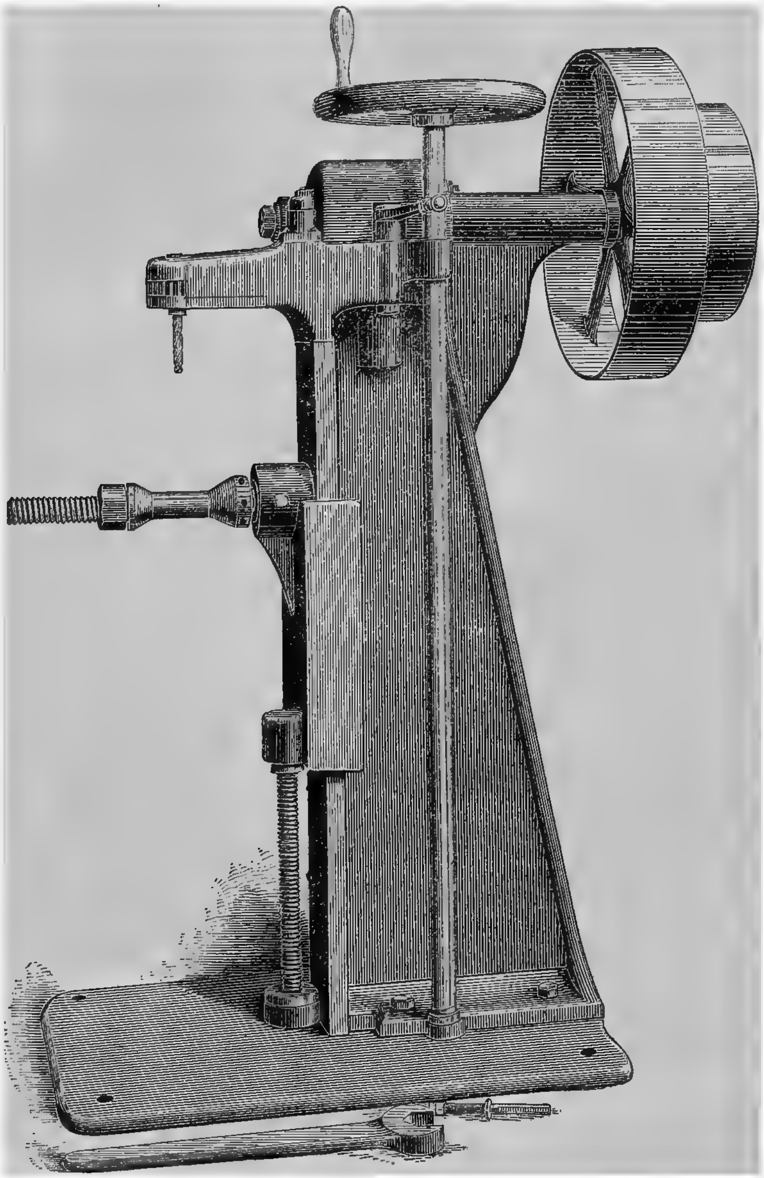


Fig. 187.

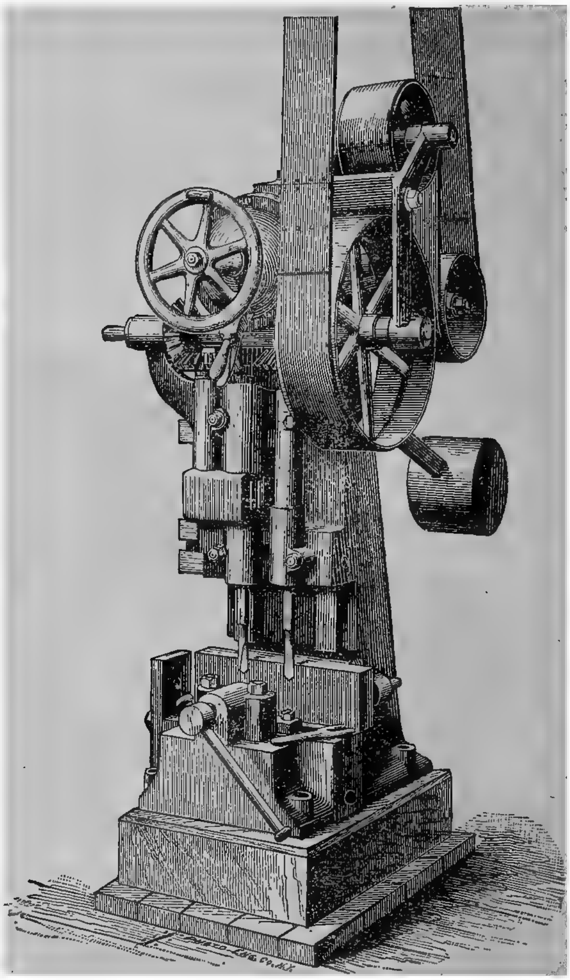


Fig. 188.

Fig. 188 shows a drill for the ends of steel rails, that the bolts for the fish-plates may pass through the web. The drills are fed down by a power-feed, positive and unvariable, the return being rapid by hand. The slide is counter-weighted, and the slack of belts is taken up by an idle-shaft linked to the driving-shaft. The rail is clamped in a vise upon the bed of the tool. These tools attain a rapid cut by high speed and fine feed. They are usually used in pairs, one at each end of the rail.

For drilling a number of holes at exact distances apart great economy of time results from the use of multiple drills. Fig. 189 shows a gang of four. The spindles are driven from a splined shaft, and can be adjusted to any distance apart greater than 7½ inches. The spindles are self-feeding and counter-weighted, and may be readily changed in relative height to suit drills of unequal lengths. The saddle which carries the drills is adjustable by rack and pinion on a cross-slide, which is long enough for sheets of 8 feet in width. The table is stationary, and the spindles are fed down by double worm-gear.

In the machine of Fig. 190 the spindles are six in number, and have no vertical feed. The machine is designed for truck-frames, and the spindles are made extensible by socket-arbors secured into the sleeve of the spindle by set-screws. The table is fed against the drills by a pair of cams driven by the worm-wheel at the right, so that the

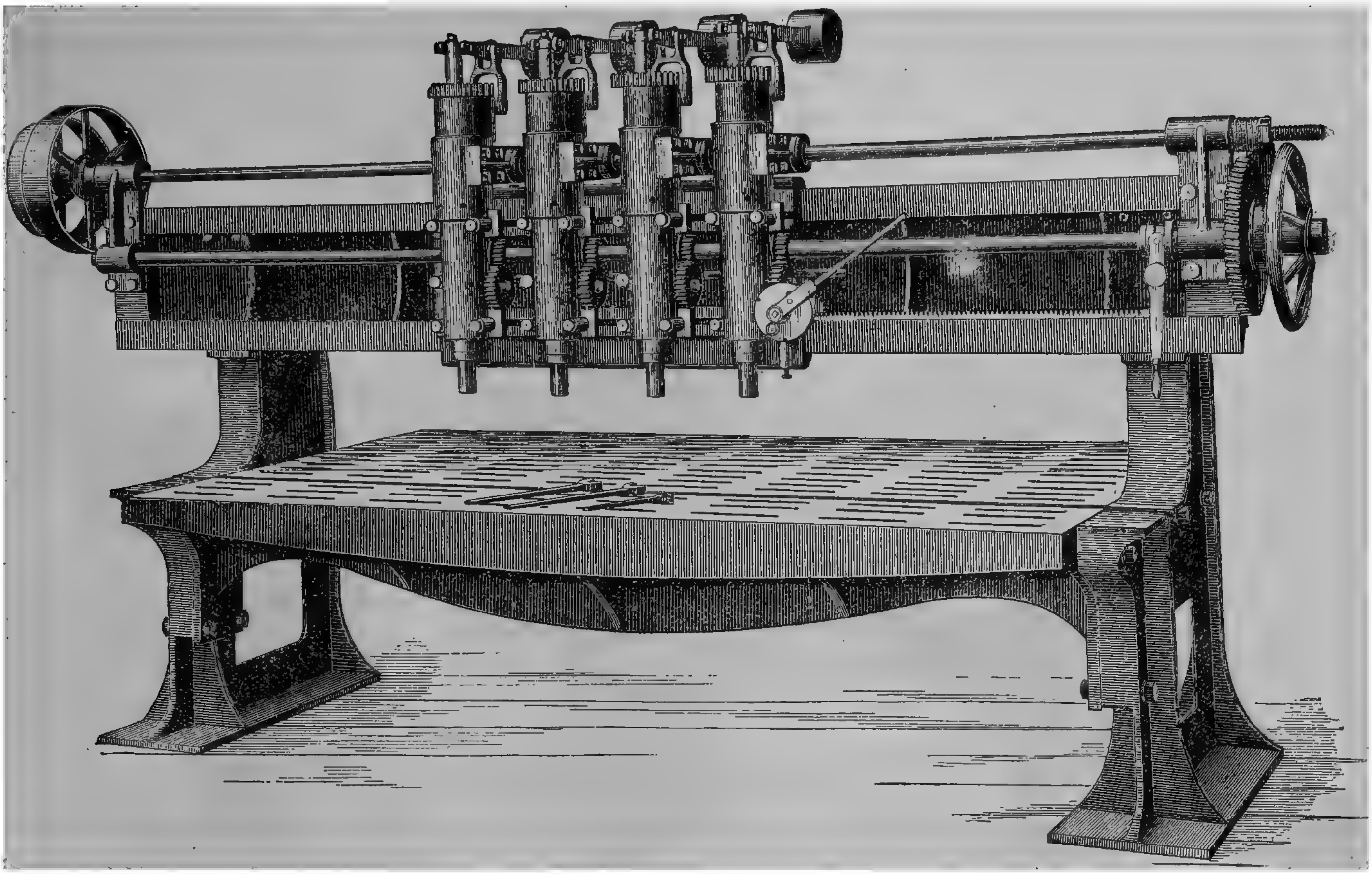


Fig. 189.

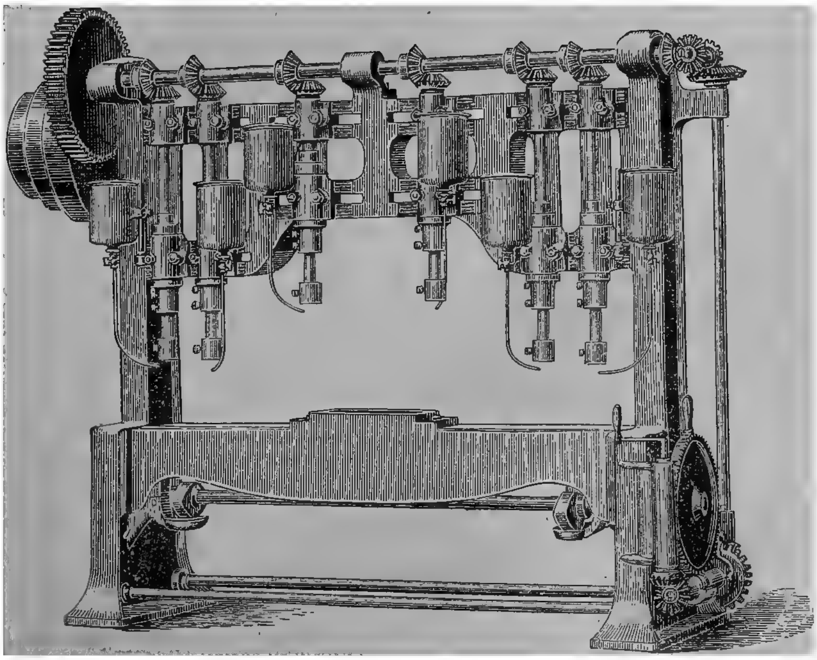


Fig. 190.

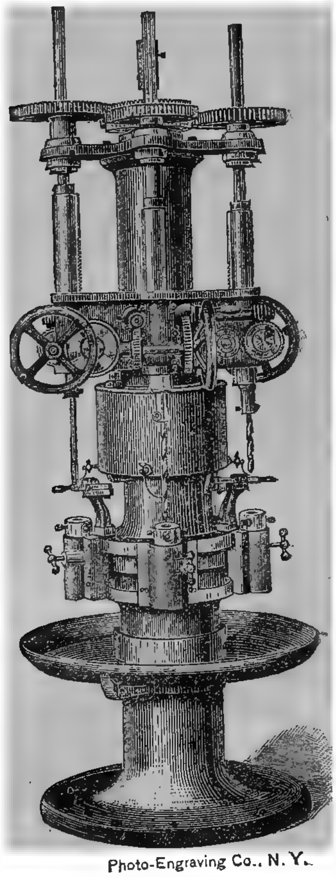


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Fig. 191.

feed and return motions are automatic. Sometimes the spindles are driven by a many-threaded screw of steep pitch, meshing into a helical gear on the spindle. This permits the spindles to be brought very close together. On account of friction, this helical system only works well against small resistances.

For a different class of work, where the holes are to be drilled deep in small work, the type of gang-drill shown in Fig. 191 is approved. It will carry a starting-drill, a through-drill, an enlarging-drill, and a reamer, or four pieces of work may have the same operation performed on them at once. The feed is automatic, and one operator can attend to several machines.

Figs. 192 and 193 show the belted gang-drill in two forms. The pulleys on the spindles may be of different

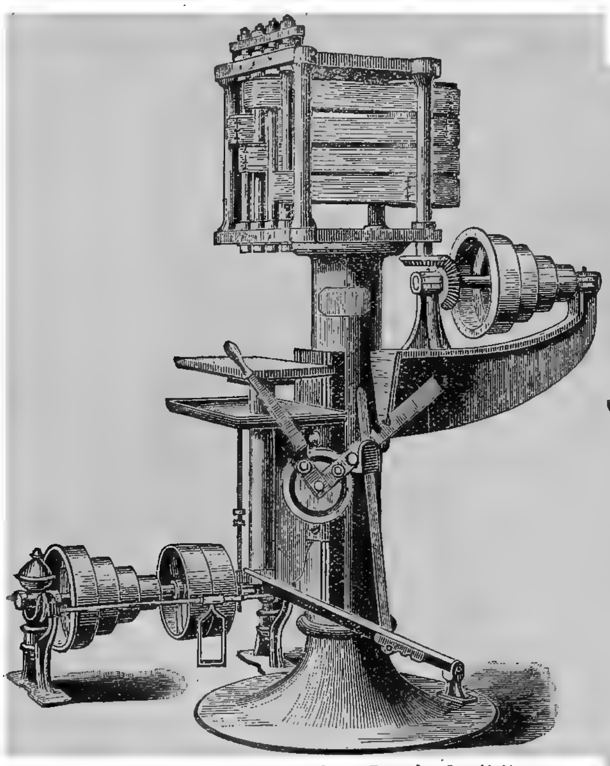

Fig. 192.

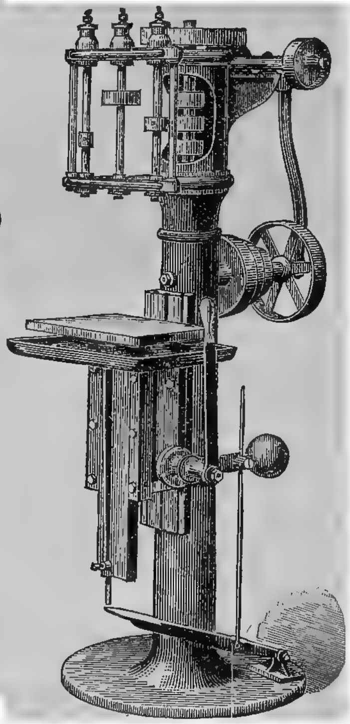
Fig. 193.

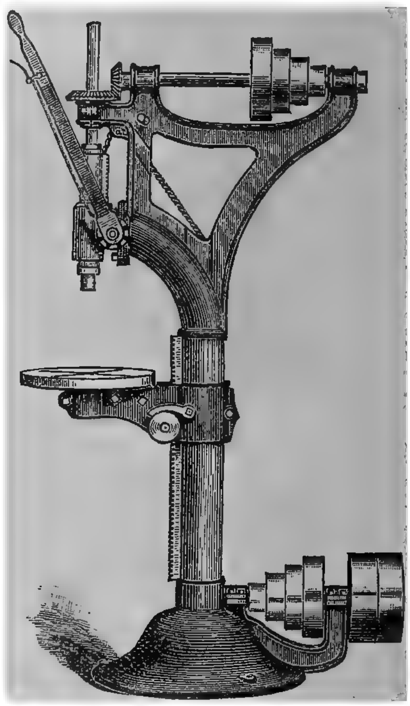
Fig. 194.

diameters if for different duties. The work is lifted against the drill by treadle or by hand-lever. The wear of the spindles is compensated for by take-up devices in the boxes, and the trouble caused by expansion of the spindles is avoided. The belts are made as long as possible.

Fig. 194 shows a type of drill approved for light work at high speeds. It makes a cheap design for a large class of manufactured articles.

Fig. 195 shows a tool for similar work arranged to have the work lift against the drill, which is belt-driven, and there is a stop device by nuts on a screw to gauge uniform depths.

Figs. 196 *a* and 196 *b* show a tool which has been approved in railroad and boiler shops on account of its limitless swing. The tool is called a suspension-drill, and is hung by the ring from the ceiling. Sometimes it is arranged so that the ring is on a carriage, which may traverse in two directions at right angles, making the adjustment of the drill-point more easy to the marks of the punch.

Fig. 197 shows a combination tool, drill, and slotter, which has found its use in certain shops. The slotter is disengaged by adjusting the wrist-pin into the center of motion and clamping the slide. The drill is fed by a screw from a worm on the spindle. It is disengaged by lifting the horizontal bevel-wheel out of gear by a milled head in the bracket.

Fig. 198 shows a special machine for drilling and countersinking centers for lathe work. The work is held by a scroll-chuck whose center coincides with that of the drill. The latter is fed forward by the ball-handle. Fig. 199 shows a similar tool, arranged vertically.

In all the tools which belong to this class of drills the workmanship in standard practice is of the best. The spindles are of hammered steel, the gears are cut, the important guiding surfaces are scraped to true planes. In the lower end of the spindle is made a taper socket, in which may be fitted a boring-bar or a secondary socket for drills. The sockets are most of them made with the Morse taper of $\frac{5}{8}$ of an inch to the foot. This is apparently displacing the so-called American taper of $\frac{9}{16}$ of an inch to the foot. At the top of the socket a slot is cut through the spindle, in order that a taper flat key driven through the slot may force out the drill without marring either

spindle or drill, and the end of the drill taper is so milled as to prevent the drill from turning in the socket, and yet it is certain to "center" as the two conical surfaces come together. The old collet and set-screw is rapidly disappearing.

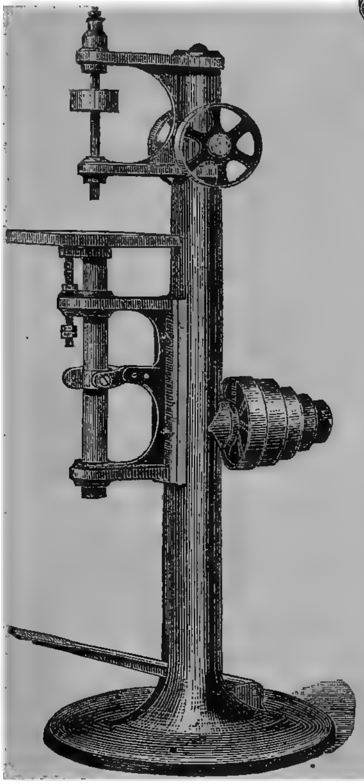

Fig. 195.

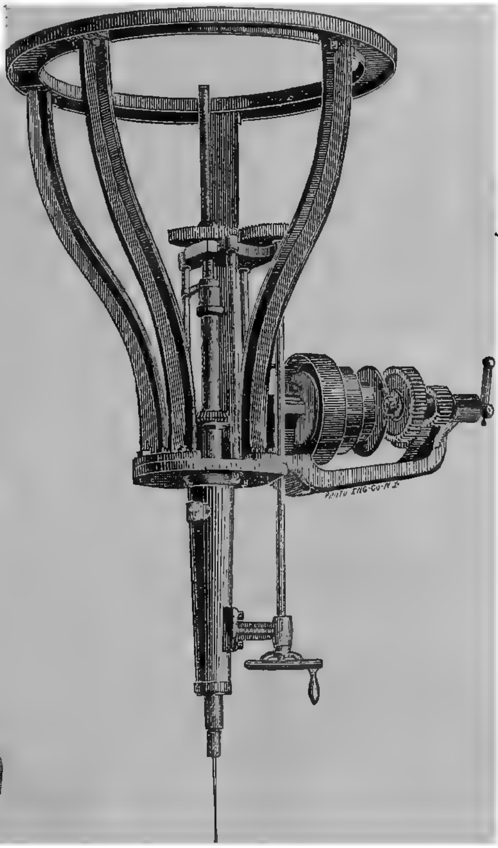

Fig. 196 *a*.

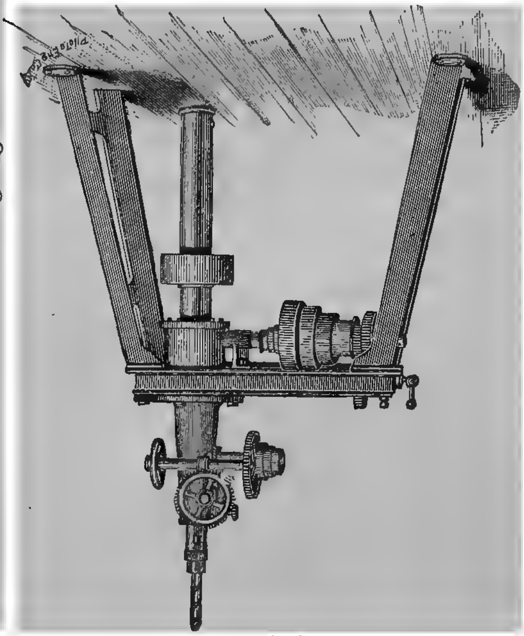

Fig 196 *b*.

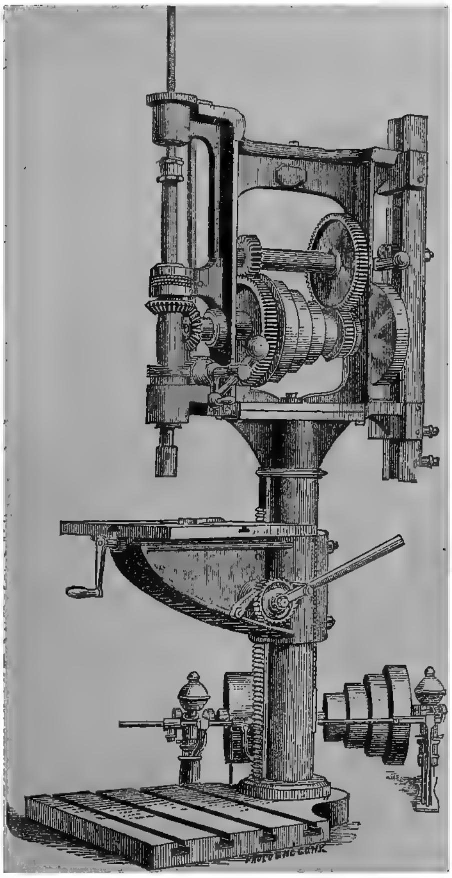

Fig. 197.

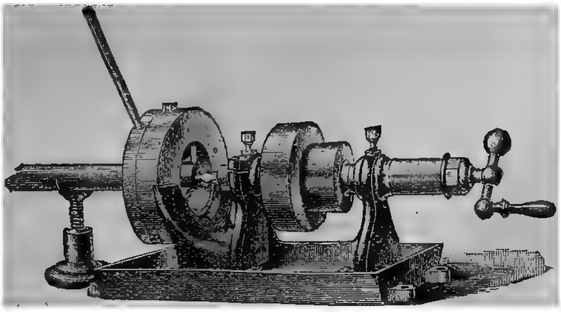

Fig. 198.

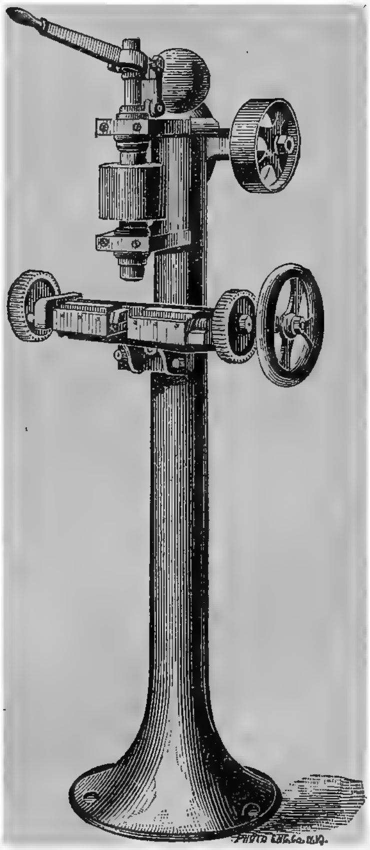

Fig. 199.

§ 24.

BOLT-CUTTERS.

These tools for producing the screws on bolts might come perhaps under the head of the lathes. They have become, however, of so much importance as to be separate machines, and to form a class by themselves. They belong to two classes. The first includes those in which the work is held stationary and the dies revolve. The second class includes those in which the work revolves, while the dies are held stationary. Advanced practice rather favors the first class. The bolt-cutters may be again subdivided into the fixed die-machines which must be reversed to release the work, and the movable die-machines wherein the bolt is released by the opening of the dies, so that the machine need not be stopped. The latter system is preferred because the integrity of the thread is not endangered by running the die backward over the thread. Any chip from the cut getting into the relief of the die may tear away or mar several threads. The movable die system is also more rapid.

There are differences with respect to the number of chasers, and the position of the cutting-points upon the

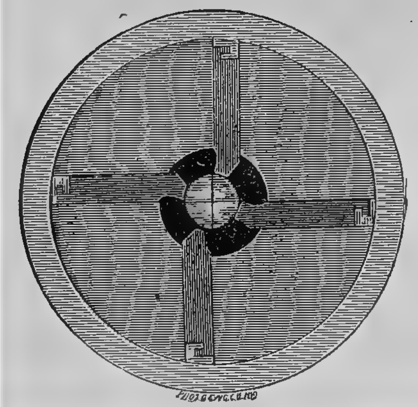

Fig. 200.

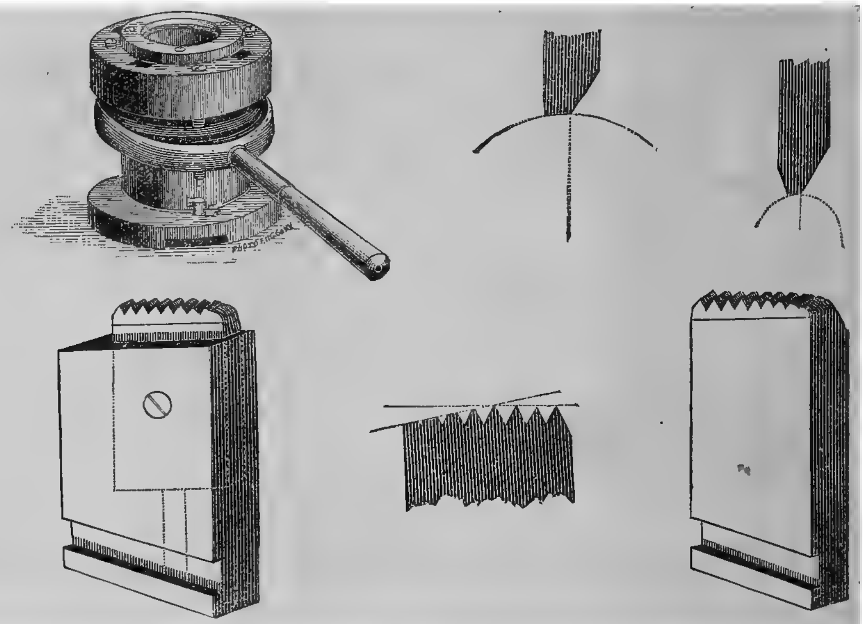

Fig. 201.

bolt. Prevalent practice prefers four cutters, although three are approved in some quarters. Against the three jaws it is urged that the rod is never cylindrical, and that when the long diameter is on any one cutter, the other two are resisting near the short diameter. This permits the stock to recede from the one cutter, and the thread will be uneven and the nuts will bind.

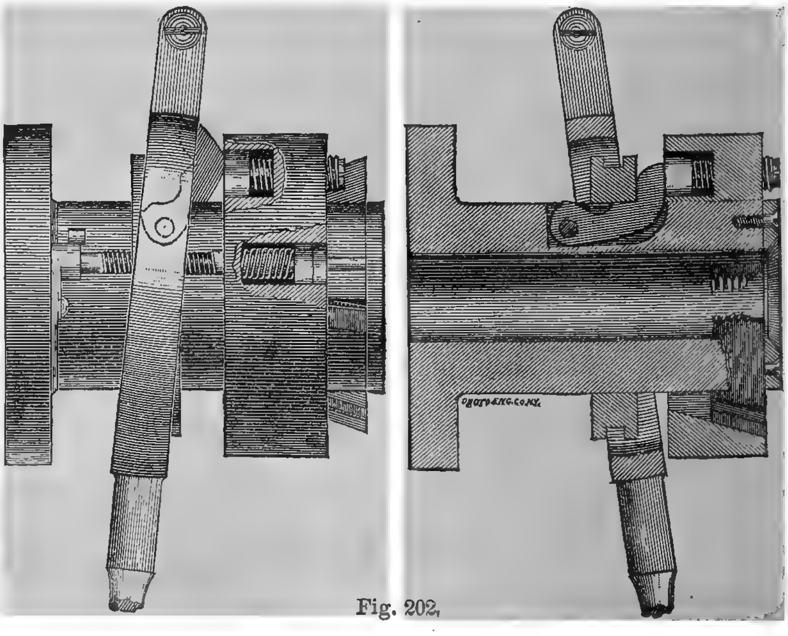

Fig. 202.

With respect to the position of the cutting-edge, the analogy of lathe practice has induced the system of Fig. 200. The cutting takes place at the ends of what corresponds to the horizontal diameter of a cylinder in the lathe. It is claimed, however, that when the cutter "leads" or cuts above the center the thread will be smoother than in the other case. On account of the play for adjustment of the jaws, a jaw nominally on the center line will often be really making a scraping cut below it. When this scraping occurs the edges tear the stock, instead of making a clean cut. Several good authorities, however, put the die on the center line, and nearly all favor the exact center for solid heads on account of lessened friction. When the dies are on the center line, the cutting or "hobbing" of the dies

is done by a master-tap larger in diameter than the size called for, to secure the necessary relief at the heels of the cutters. When the cutters lead the center a smaller tap is necessary for the same purpose. The adjustable heads make this variation in size very easy while being cut.

Fig. 201 shows the hand-relief given to the tap, to give only the required amount of cutting-face, and also the relief for the entrance of the blank. The length of the cutting-face will vary with the speed and the severity of the work of the cutters. The same figure shows a case-die, in which the die proper is held in a holder. After being properly shaped the cutters are hardened, the threads being coated with soap to prevent scaling. The temper is drawn to a medium straw color, and the quenching is done in linseed oil or in water. The oil is thought to toughen the steel. While domestic steel has given results fully equal to those of imported grades, the tool-makers complain of the lack of uniformity and reliability which they encounter in its use. On this account only the imported product is preferred to the American at this date.

Fig. 202 illustrates one of the types of adjustable head in very general use. The dies fit in rectangular slots, by which radial motion alone is permitted. The dies have an oblique gain or mortise on one side, which fits a corresponding tenon in the external chucking-ring. When, therefore, the ring is moved forward the dies will close inward. When it is moved backward, the dies will open and release the bolt. The position of the heavy ring, and therefore the size of the thread cut, is determined by a small latch, which is held and released by the grooved ring pinned to the lever. This latch abuts against a screw in the heavy tenon-ring, which may be set at pleasure. The head is retracted by the long screws which pass through the tenon and grooved ring, thus uniting them together. The end of the long screw abuts against a stop, to prevent the rings from coming back too far. When this stop is swung out of the way, the dies are released, and can be exchanged for others. The shifting of the lever can be made automatic, so that the dies may be released when any desired depth of thread is reached. The entire machine is shown by Fig. 203.

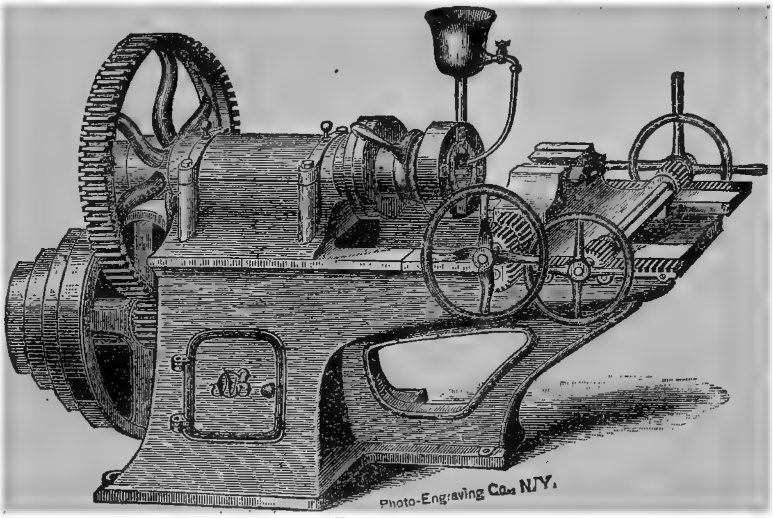

Fig. 203.

Fig. 204 shows a similar device for setting the jaws. The machine is entirely automatic. When

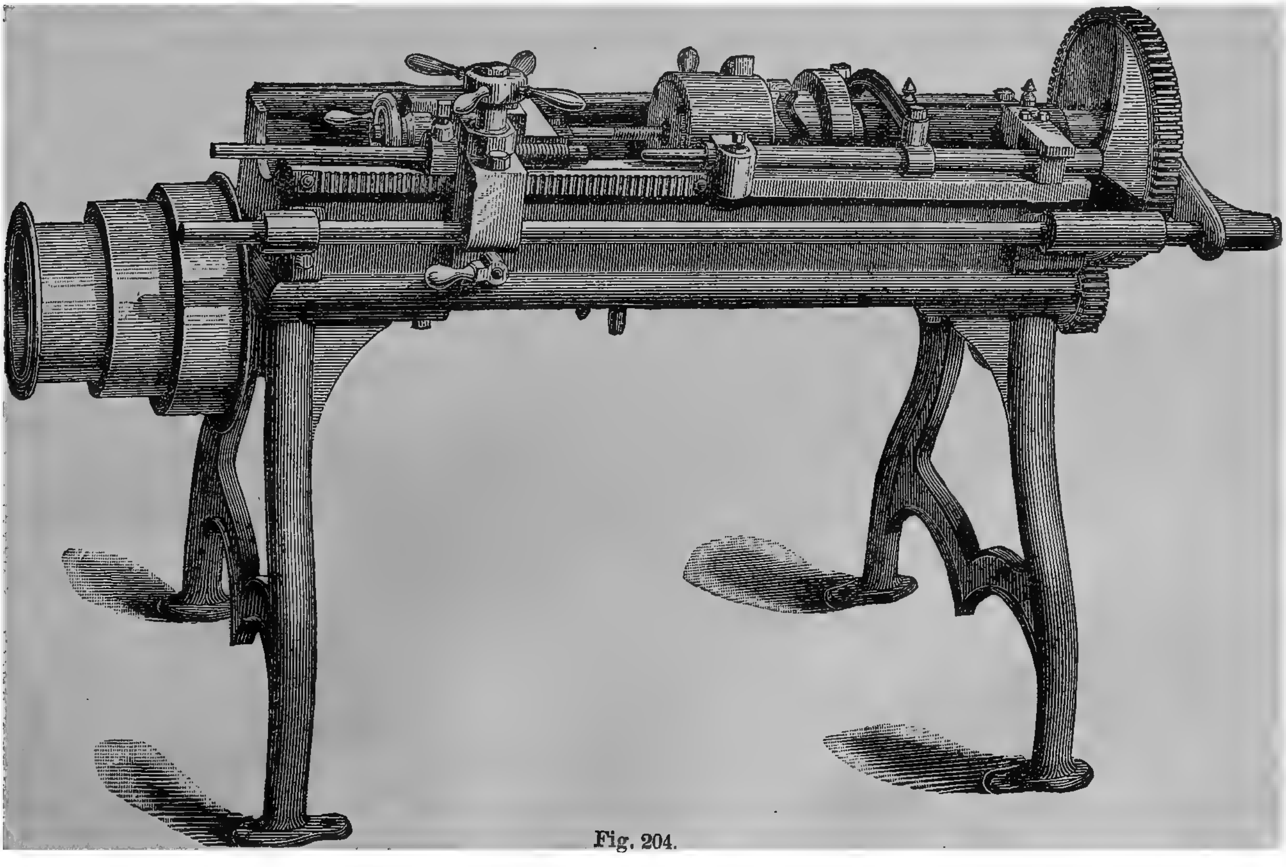
Fig. 204.

a latch is engaged with the ratchet-tooth on the head at the proper depth the outer ring is arrested and the flat groove on the inner sleeve retracts the keys on the jaws by virtue of its continued motion. At the same time the inclined plane on the large gear forces back the carriage and the finished bolt. The continued motion of the inner sleeve resets the jaws and locks them by the straight part of the groove. These tools are also arranged to hold the bolt between centers while being cut, in order to secure the same diameter of all threaded stock.

Fig. 205 shows another type of automatic machine, and Figs. 206 and 207 show its details. Three dies are held in radial slots in the head which is driven by the outer and larger gear-wheel M. This wheel is fitted loose on the hollow spindle B, and is secured to the latter by two bolts. These pass through the plate of the wheel and through circular slots in two arms, D and D′, which form part of the main spindle B. The position of M upon the spindle B is thus adjustable, and may be noted by a pointer, d, on the arm D, which moves over a scale upon M. The inner and smaller wheel, M′, is keyed to an outer sleeve, B′, which fits over B and carries a set of three cam-plates, b, upon the flange of the head. These cams are milled out on their inner edges to a spiral curve. These curved edges resist the radial motion outward of the dies when cutting, and it will be seen that the opening between the cutters will be determined by the relative position of the sleeve B′ and the driving-spindle B. If B′ were to revolve faster than B, the cutters would abut against a surface of b, which would get gradually farther from the center, and the dies would open. The wheel M′ is driven from the wheel M when the tool is cutting by projections E E upon their hubs. When these projections are in driving contact, any desired relation between the dies in B and the cam-plates upon B′ may be secured by bolts in the slotted arms D and the index pointer d. Any adjustment for wear, or any varied sizing of thread, large or small, may thus be effected. The large wheel M is driven from a pinion, F, keyed on the cone-pulley shaft. The wheel M′ meshes into a little larger pinion, F′, loose on the same shaft. A spiral spring, I, abutting against an adjustable collar, K, presses F′ against F, the adhesion being increased by a leather disk between them. When the spring is permitted to act, F will drive F′ by friction until the projections E upon the hubs come in contact, when the friction-disk will slip and B and B′ will move together. But F′ may be moved by the hand-lever H and the counterweight L so as to bring a male cone on it into a female cone which is fast in the leg of the machine; this arrests F, M′, and B′, while B still moves. Small spring cams, c, move out the dies in the head as they are relieved from the spiral of b, until the projections E on the hubs engage on the other side. The head then turns with the dies open until the lever H is latched back, when the spring I is permitted to act and the dies slowly close by the more rapid motion of M′ and B′. A rod in the axis of the cutter-head may be set to release the latch of H when any desired length of thread has been cut. This compact method of causing different relative speeds in the two large gear-wheels and utilizing the differential motion for moving the dies renders this a very notable machine.

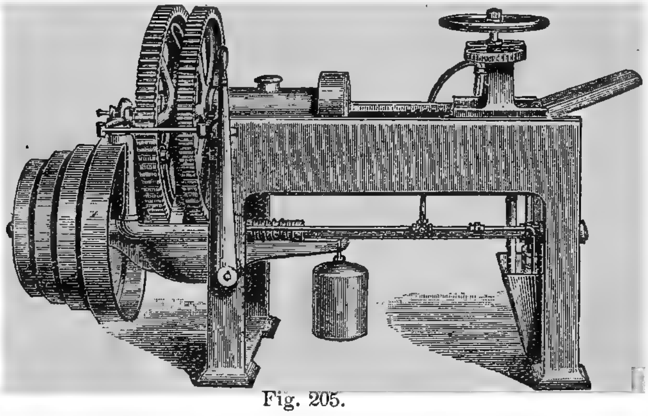

Fig. 205.

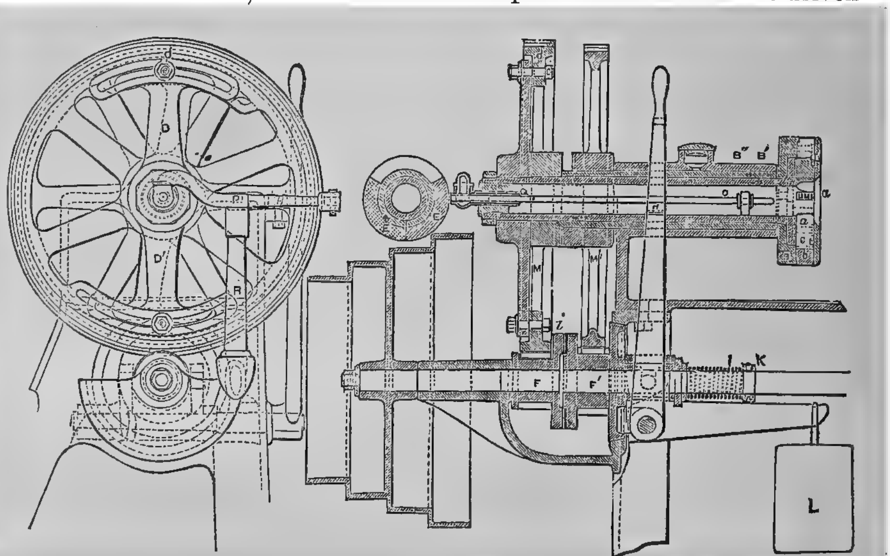

Fig. 206.

Fig. 207.

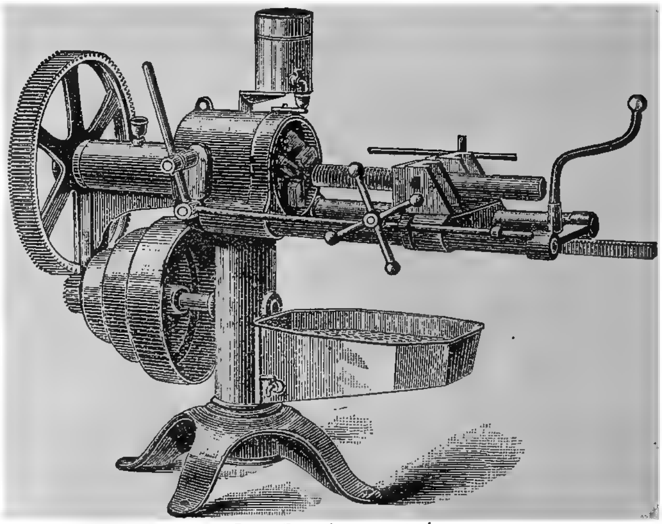

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Fig. 208.

The tool shown in Fig. 208 illustrates another arrangement. Each of the cutters is carried in a species of holder made of a steel casting. The die is held in the holder by two set-screws on the side and one on the end. The holder has a turned stud near one end whose axis is parallel to that of the bolt to be cut. This stud fits into the head so that by the rotation of the holder around the stud the cutter-jaws approach or recede from the center. The holders are forced and held to their cut by a pin with inclined end, which moves parallel to the axis of the head and bears upon the back of the holder. The motion away from the cut is effected by stiff springs. These holding-pins are attached to a sleeve, which is moved forward by a spiral spring, and is moved backward when a pin is

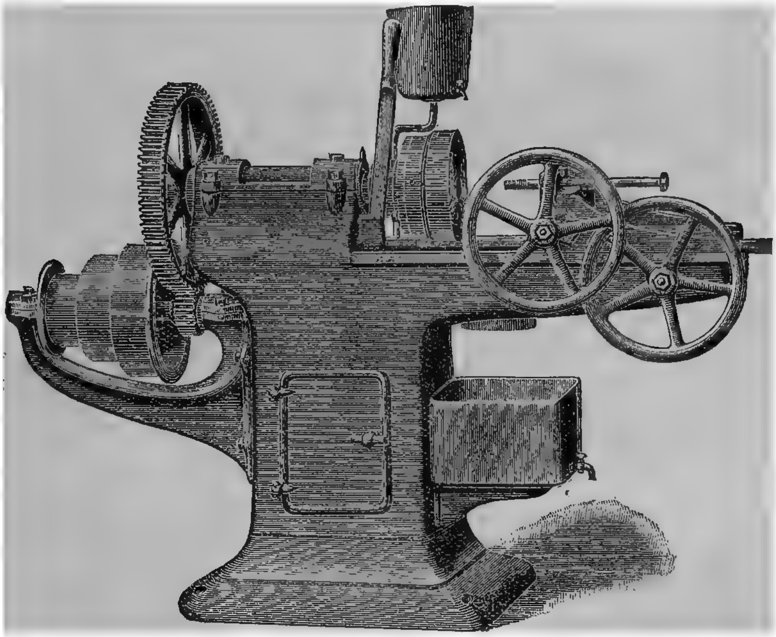


Fig. 209.

released by a latch and drops into an inclined groove in the sleeve. This latch is moved by the bolt being cut, so that any desired length of thread may be produced. The bolt-cutters of Figs. 209 and 210 show the standard New England form of this type of machine.

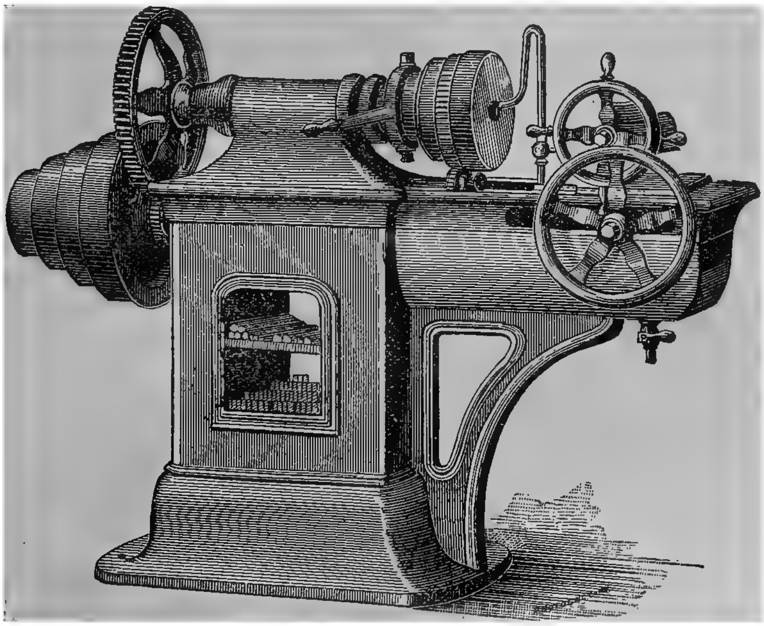


Fig. 210.

Fig. 211 shows one of the largest machines of this class ever made, designed to cut the threads on 6-inch rolled iron. It was first built for the heavy bolt and turn-buckle work in the pumping and hoisting plants in deep mining in the state of Nevada. The machine weighs 10 tons, the large gear is 5 feet in diameter, and the 6-inch tap alone weighs 200 pounds. The same builders make smaller machines, presenting the same advantages as the other designs.

All these machines are fitted with self-centering jaw vises for holding the stock (Fig. 215). In one type the vise is geared differentially, giving great power. Usually the jaws are worked by screws only, either right-and-left handed, or else geared together. They are fed forward to the jaws by a rack and pinion and hand-wheel, or else by a lever. The designs and motions of the vises are shown in the cuts.

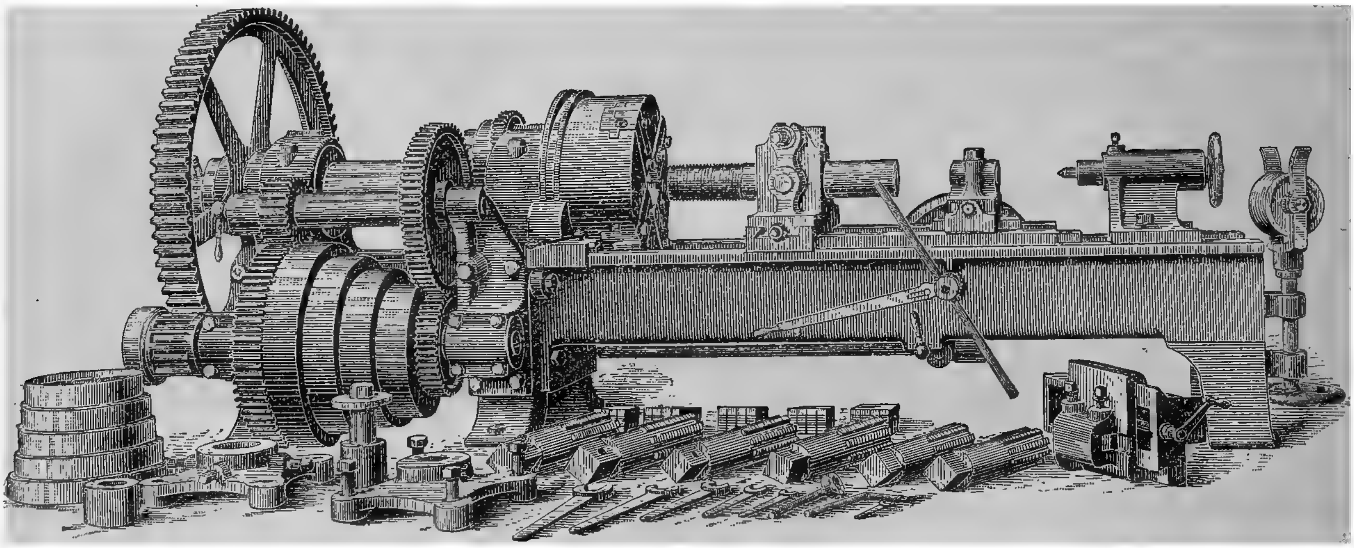


Fig. 211.

For bolt-cutters of the second class, where the bolt revolves and the die is stationary, a solid die is used. One of the types is shown by Fig. 212 *a* and *b*. The cutting-chasers are inserted in an iron collet, encircled by a wrought-

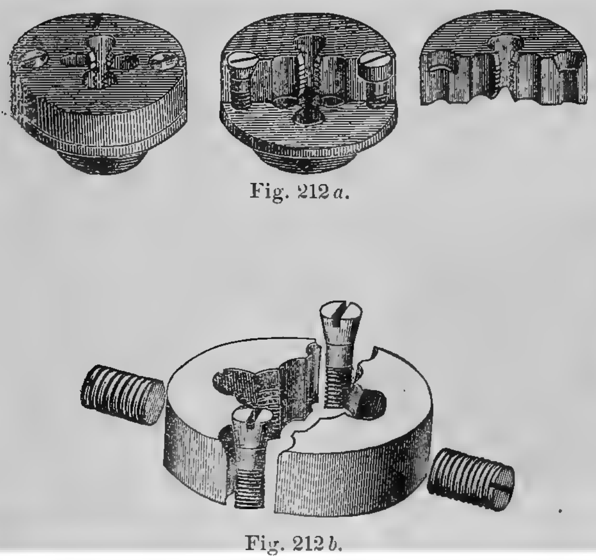


Fig. 212 *a*.

Fig. 212 *b*.

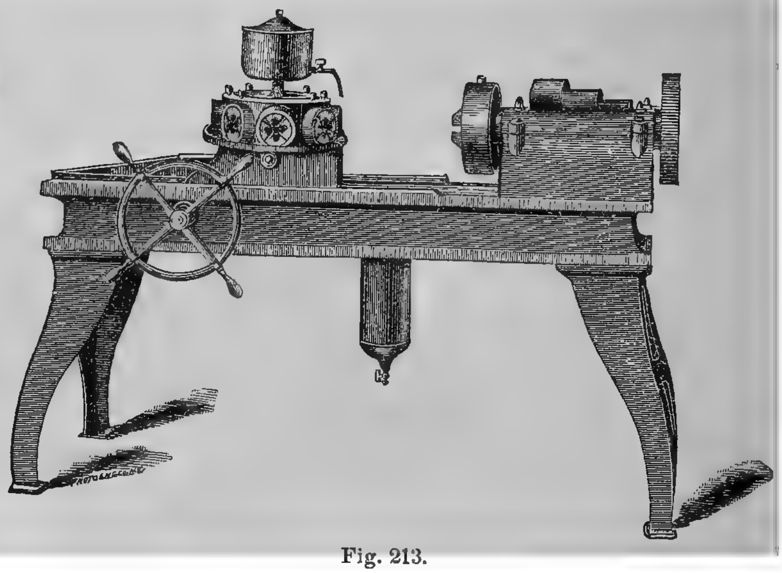


Fig. 213.

iron ring, beveled on the inside. The chasers are beveled to fit the ring, and the latter is secured to the central flange of the collet by adjusting- and distance-screws. An adjustment of $\frac{1}{32}$ of an inch or more may be made in the cutting size of each die. The collet is split, and the opening may be lessened by slacking off the conical screws.

Figs. 213 and 214 show the types of the entire machine. A number of dies are held in a turret-head, and are fed against the revolving bolt by the hand-wheel, pinion, and rack. In Fig. 214 a slide is fitted with sockets for various sizes of nuts. The taps will be held in the jaw of the head (Fig. 215).

A type of movable jaw-head for cutters of this class is shown by Fig. 216. The cutters fit into chuck-plates, which have spiral grooves in their back. The size of the thread will be determined by the position of the stop in the curved slot at top. The blank is released by the revolution of the holder by the hand-lever shown. For tapping-nuts any of the machines illustrated may be applied directly by the simplest inversion, or by replacing the cutting-jaws by a pair adapted for holding a tap.

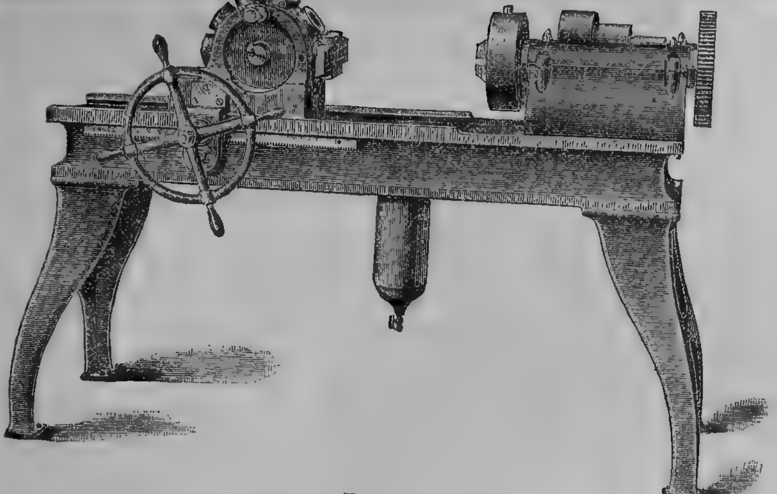


Fig. 214.

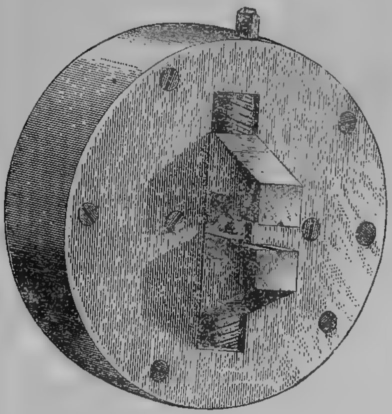


Fig. 215

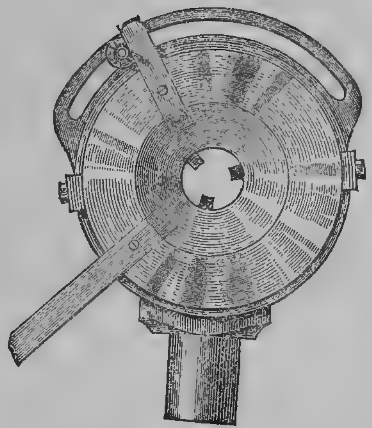


Fig. 216.

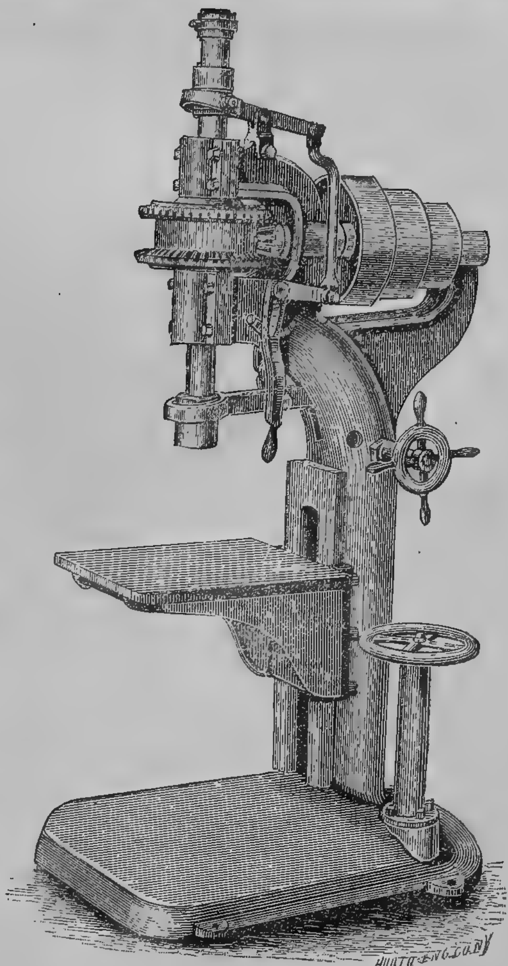


Fig. 218.

Fig. 217.

Fig. 217 illustrates a multiple vertical machine of six spindles. The spindles are counterpoised, and the nuts are immersed in oil while being tapped, and slide into their fit in the holders. The vertical tappers have the advantage of washing away the chips from the cutting-edges. On the other hand, in the tank-machines the tap may revolve in a film of oil on the surface of water. The water cools the tap, and the oil relieves the friction. The

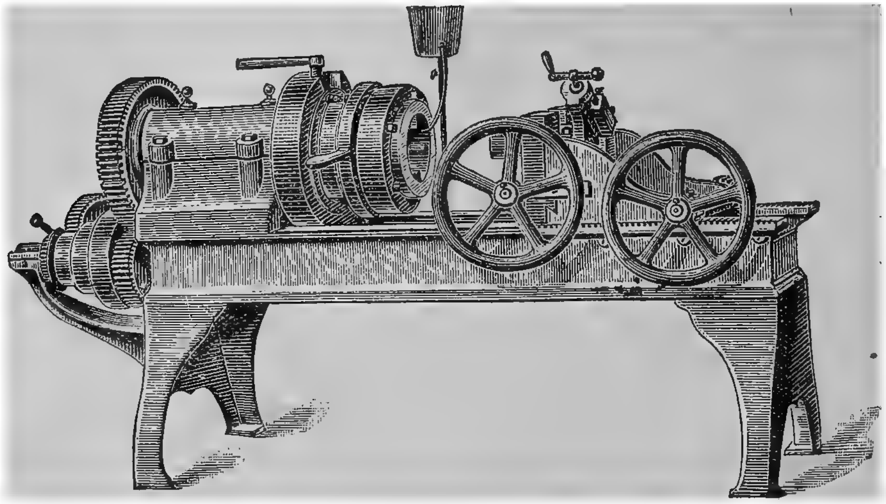


Fig. 219.

mineral oils do not answer for these purposes. Animal oils must be used, or a soda water, or an alkali mixture, made up of 10 pounds of carbonate of soda, 4 gallons of whale oil, 3 gallons of lard oil, and 40 gallons of water. These lubricant mixtures are either held in cans and delivered from a long spout at the cutting-point, or else are pumped on the work in excess to wash away the chips. The spent oil is strained into a reservoir and used over and over again, whence results a notable economy.

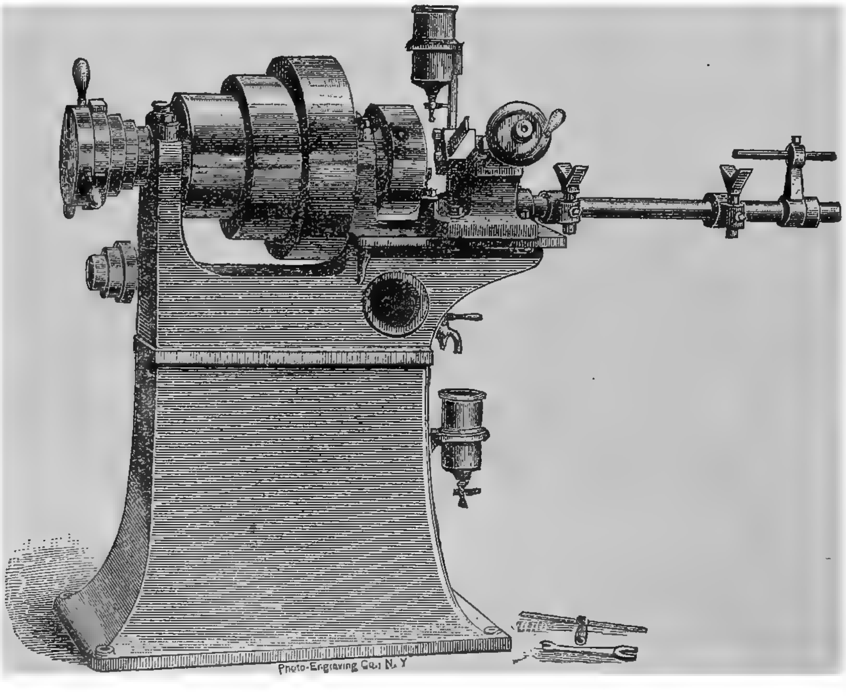


Fig. 220.

Fig. 218 illustrates a machine for tapping general work in cast iron, where the work will be run dry. The spindle is driven in one direction or in the other by a clutch between the horizontal bevel-wheels, which is operated by the lever. The spindle is fed down by hand, and the table is adjusted by screw and hand-wheel.

The machines for threading pipe differ in no essential respects from the bolt-cutters. The smaller sizes are usually worked with solid dies, the pipe being held in jaws in the head and passing through the hollow spindle. The larger sizes use adjustable dies in a revolving head (Fig. 219). Where the pipe is held stationary the required length may be cut by fed cutters in the head. Where the pipe revolves, the lengths must be cut either by a cutting-

off tool, on a rest, or else in a separate machine. This latter class of machine is known as a cutting-off lathe, and types are illustrated by Figs. 220 and 221. The spindle is hollow, with a jaw at one end and a bushing, or, better,

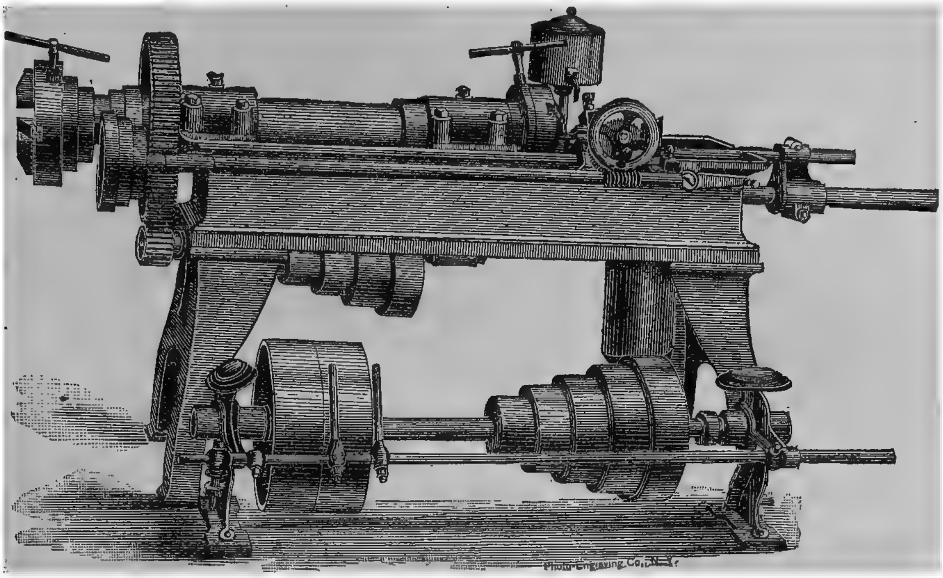


Fig. 221.

a self-centering chuck, at the other. The tool is fed obliquely downward by hand and by power, the required length being gauged by a stop. The tool may be forged of such a shape as to be efficient until it is ground so short as to become useless. Tools in holders are frequently used.

§ 25.

SCREW-MACHINES.

For making machine- or set-screws from the bar which has the shape for the head, a screw-machine is required. This may have several forms. For large work, a machine of the type of Figs. 222 and 223 would be used. The

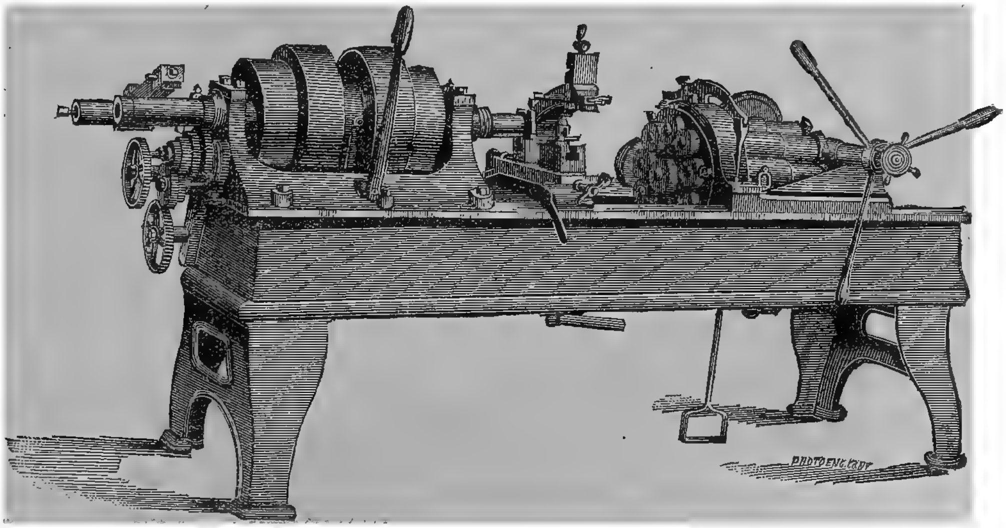


Fig. 222.

spindle is hollow and receives the rods. The tail-head carries a number of spindles, each of which is adapted for one operation on the screws. The tools are fed forward by rack and pinion by the levers, and the one in operation is held from motion by a pin on the treadle-lever. Larger screws will be chased by the slide-rest and hobs; smaller ones will be cut by dies in one of the spindles.

Fig. 224 shows a similar arrangement of tools. The linear motion is assured by the slotted disk on the tail-disk spindle, and an adjustable stop controls the lengths. Tools of this type may use tool-holders with detachable cutters for sizing, etc., thus avoiding the expense of hollow mills.

Fig. 225 shows the very usual application of the turret-head for this class of work, with a chasing-rest.

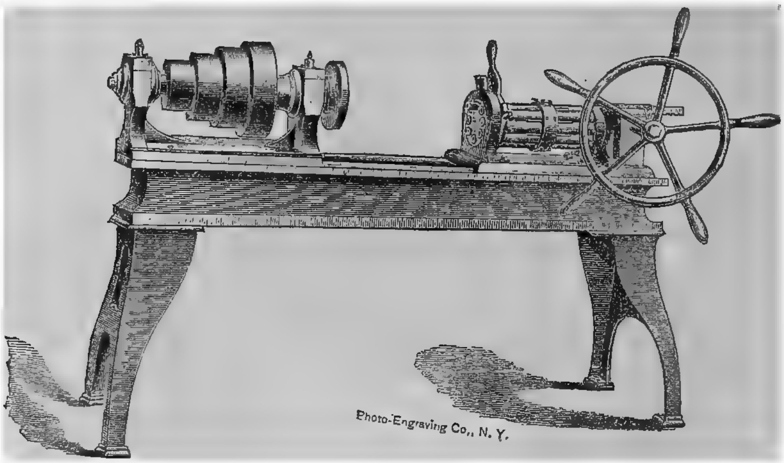


Fig. 223.

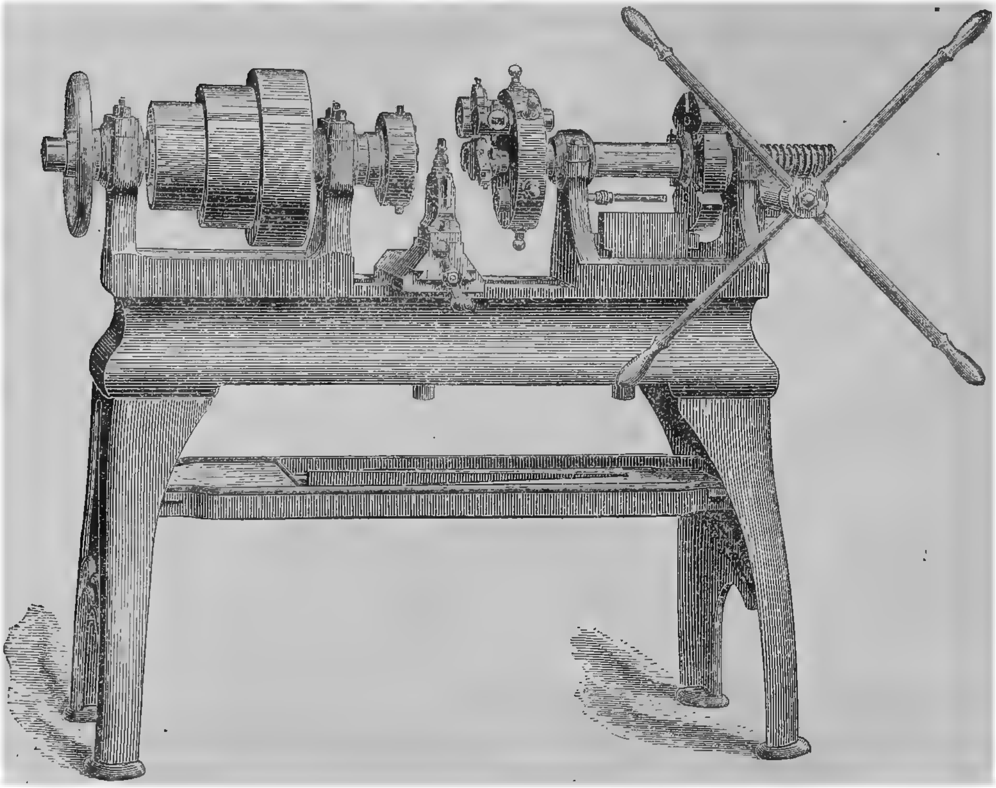


Fig. 224.

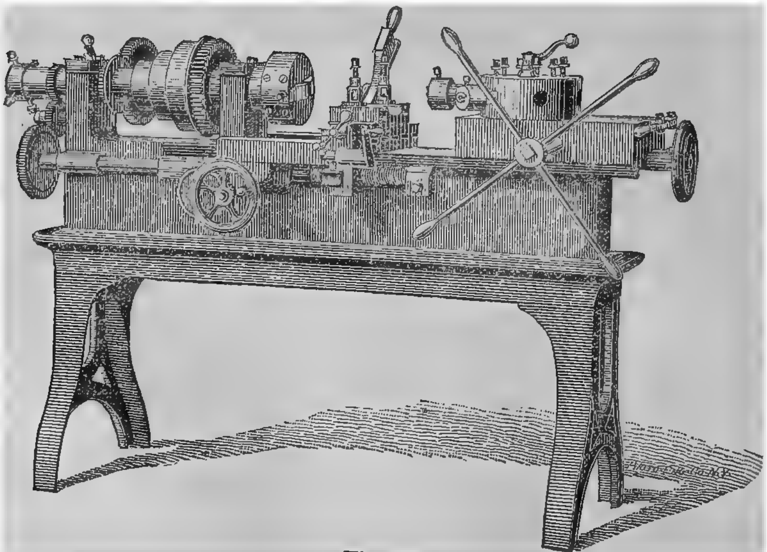


Fig. 225.

Fig. 226 illustrates the smaller machines without chasing-head the slide-rest being used for sizing and cutting off only.

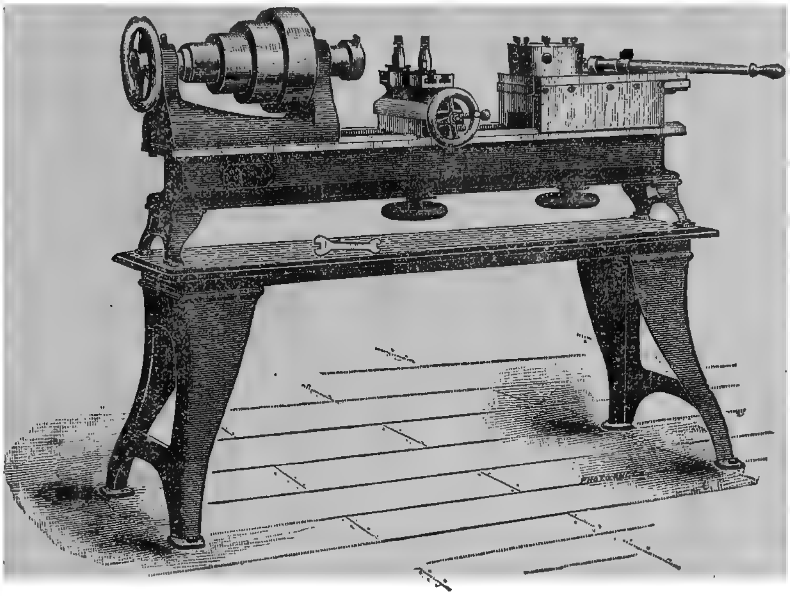


Fig. 226.

Fig. 227 shows the detail of this rest, giving the stop and gauge adjustment at the left, and Fig. 228 illustrates types of tools and holders. Machines of this class are capable of doing a great variety of work with very close

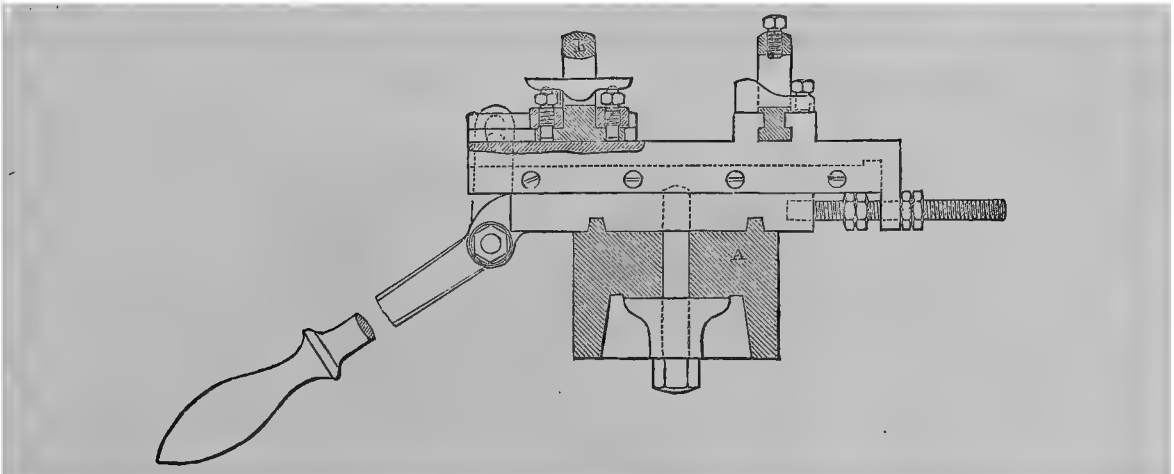


Fig. 227.

accuracy and at high speed. They are especially adapted for finer grades of work, and when so applied will operate to a margin of error within $\frac{2}{1000}$ of an inch.

Fig. 229 illustrates specimen products of such a machine.

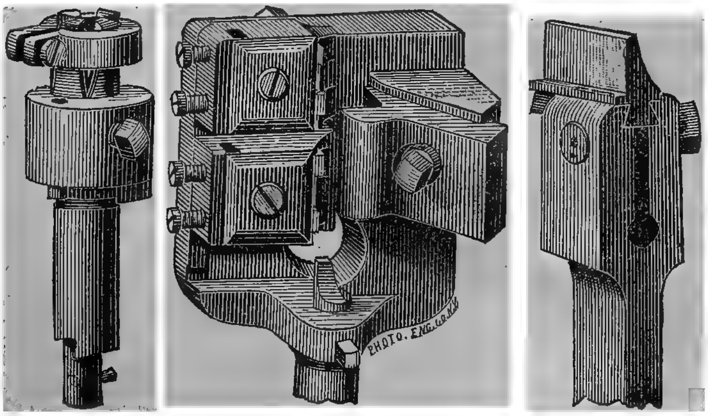


Fig. 228.

Fig. 230 illustrates a type of screw-machine, designed to give better support to the turret. The turret swings on two horizontal supported journals, instead of on one overhanging stud. The tendency to wear the turret loose upon its supports is thereby reduced. Several of its other excellencies are visible from the cut.

The smaller screw-machines are usually equipped to produce the sharp V-thread, which remains in very general use at distances from the centers of enterprise. The larger tools cut the flattened V-threads of the American standard unless specially ordered otherwise. Pipe-threads are uniform all over, and consist of a sharp thread cut with a taper of $\frac{3}{4}$ of an inch to the foot.

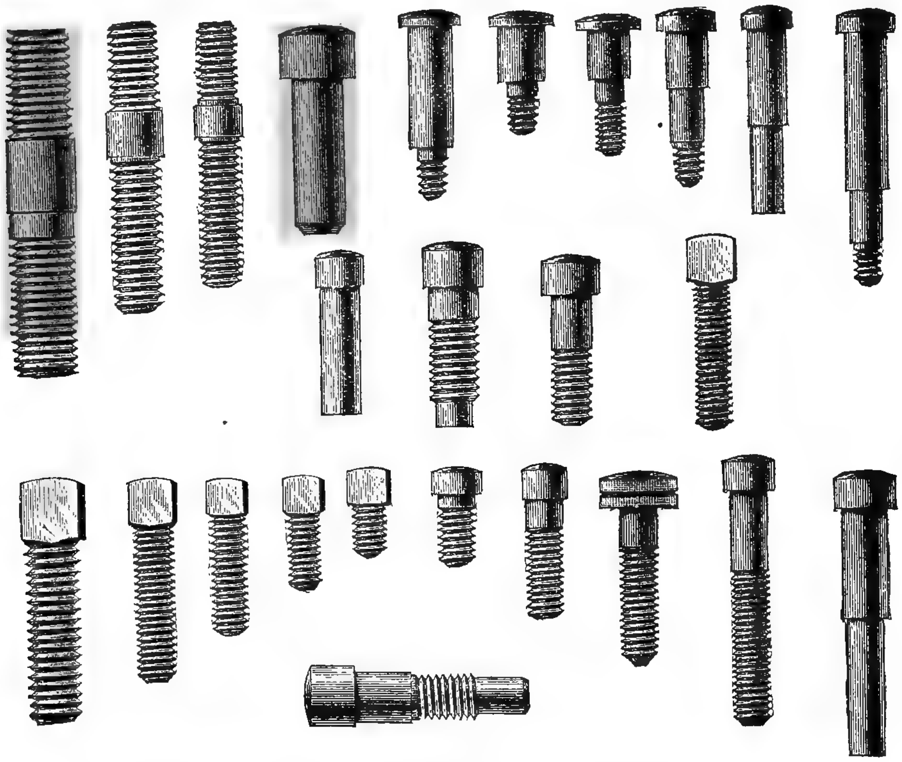


Fig. 229.

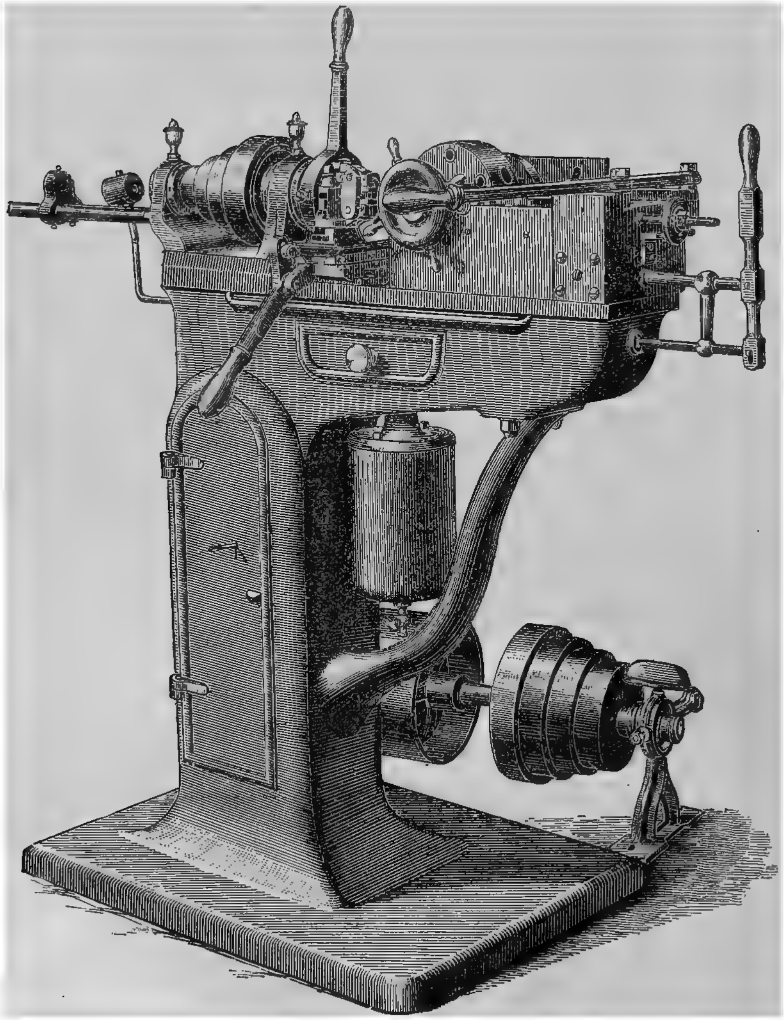


Fig. 230.

§ 26.

PARING-TOOLS WITH LINEAR MOTIONS—PLANERS.

The tools with rectilinear motions of work or of the cutter are especially adapted for producing plane or flat surfaces. The shaper and slotter are adapted for smaller work, or for work where the tool traverse need only be short, and they will readily work out curved profiles by cutting along their elements. But the planer is especially applicable for the production of large or long surfaces which must approach true planes.

The planer will consist of a table or platen moving backward and forward upon ways in a bed-casting. This table moves below a cross-head, which is borne upon two uprights, bolted to the bed-casting. The tool is secured to a slide upon this cross-head, and receives feed-motions in different directions. The gear for driving and feeding are the points in which there is the greatest divergence in the practice of to-day.

There are several reasons for making the table and the work move under the tool, which is stationary, except for its feed-motions. If the tool had to travel any distance, it would be very difficult to produce true horizontal planes. The overhang of the tool, varying at different points, would cause the chip to be always lighter when the slide was farthest out. Beside, the freedom of the slide for ease of motion would cause errors. By reversing this system the tool has its lost motion a constant, for the play of feed is the same at all points of the surface. Moreover, the weight of the table and work acts in the same direction as the strain of the cut, all being downward upon the ways of the bed. The play for motion is therefore resisted by the constant weight of the table and work, and there can be no yielding of the support for the work. If, therefore, the ways be true, and the upright and cross-head are stiff enough, true planes will be produced by this system. There is less gained by this form of tool when planing vertical surfaces. But its capacity for this class of work is small on the medium sizes, on account of the proper support of the tool. When these smaller machines are called on to do extensive vertical surfacing it is not unusual to invert their system and secure the work to a floor-plate, while the tool-holder is bolted to the bed,

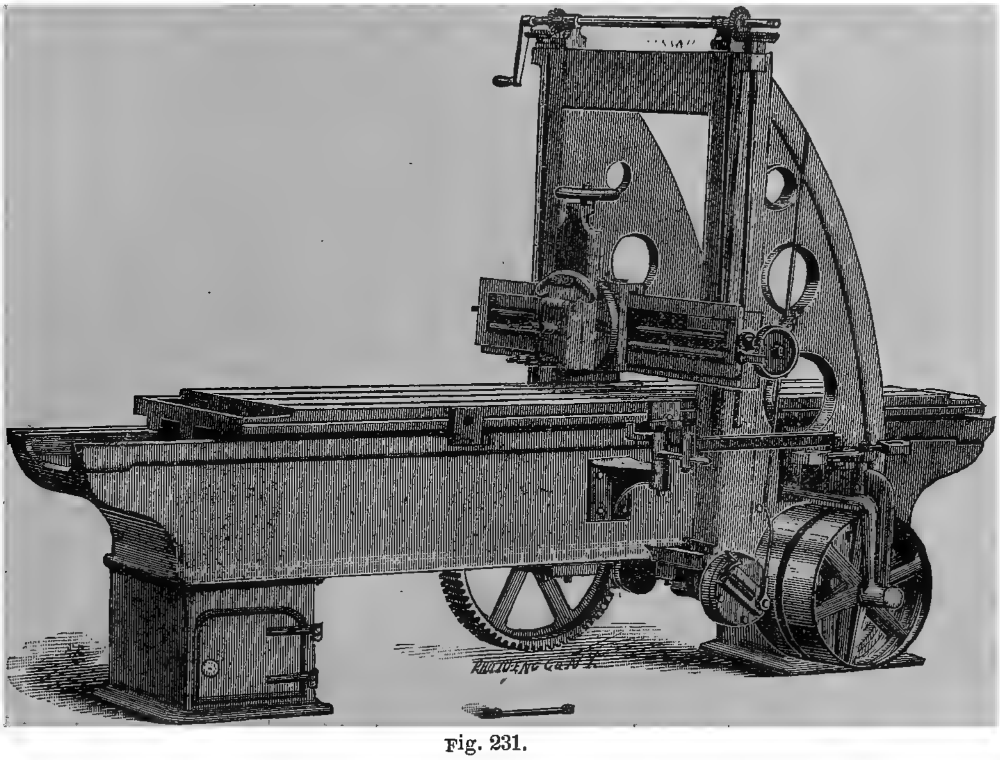


Fig. 231.

and thus reciprocates. The larger machines have vertical surfacing holders upon their uprights. For the convenient holding of work the tables or platens are cast with a large number of T-holes. T-slots are often planed in the top in addition. Upon the under side of the table are two longitudinal V-guides, planed and scraped, truly parallel. These V's rest in corresponding ways in the bed, and guide the motion of the table in a true straight line. The table is often cast with the top side up, in order that any blow-holes or defects may come in the upper side, so as to secure the soundness of the V's. The trough-shape of the lower V's enables them to retain the oil necessary for their lubrication. This could not be done were the arrangement of the V's reversed. To insure the lubrication of all the bearing-surface of the guides, curved channels are chipped out from the faces, running from the bottom of the V to near the top. By this means the oil is carried to those places from

which it would naturally drain off. It has been suggested to use flat, thin disks, which might turn in counterbores in the ways and effect the same purpose. To catch the oil which would be displaced from the ends of the **V**'s a cell or pocket is put at the ends of the troughs, and one designer planes a bead on a flat at the top of the troughs to prevent loss of oil over the sides. An objection to the use of the two **V**'s results from the difficulty in securing perfect parallelism of the four planes of the guides throughout their whole length, or of retaining that parallelism where the surfaces wear. If there is any difference in the hardness of different parts of the bed and table castings, the wear at different places will be uneven. If this wear be on one side of the **V**'s, the table will crowd over and produce curves on vertical cuts. If on both sides, the table will either dip or wind, producing errors of horizontal surface. To avoid the tendency of the bed to creep and bear a little harder on one side of the **V** or the other one designer uses one flat and one **V** groove. The bearing area of the two is calculated carefully to compensate for the different angles of resistance to the downward pressure (Fig. 231). A form of planer with two flat shears offers certain points worth noting. The surfaces for wear and bearing are large and are easily made true. Side-play is prevented by adjustable gibs. Special oiling devices by flanged rollers counter-weighted so as to lift oil against the under sides of the slides prevent dry seizure of surfaces, and they promise excellent results of exactness and durability.

The bed of large planers will rest directly on the foundation, which will oppose any flexure from the strain of the weight or the cut. On the smaller sizes the bed must be made deep enough so as not to sag between the legs or supports which lift it from the floor. There has been considerable improvement in this respect in the newer designs. A very excellent arrangement is to lessen the span between the legs by making them columnar and hollow, to serve as tool-closets. The ends of the troughs are strongly bracketed out beyond the legs for the same

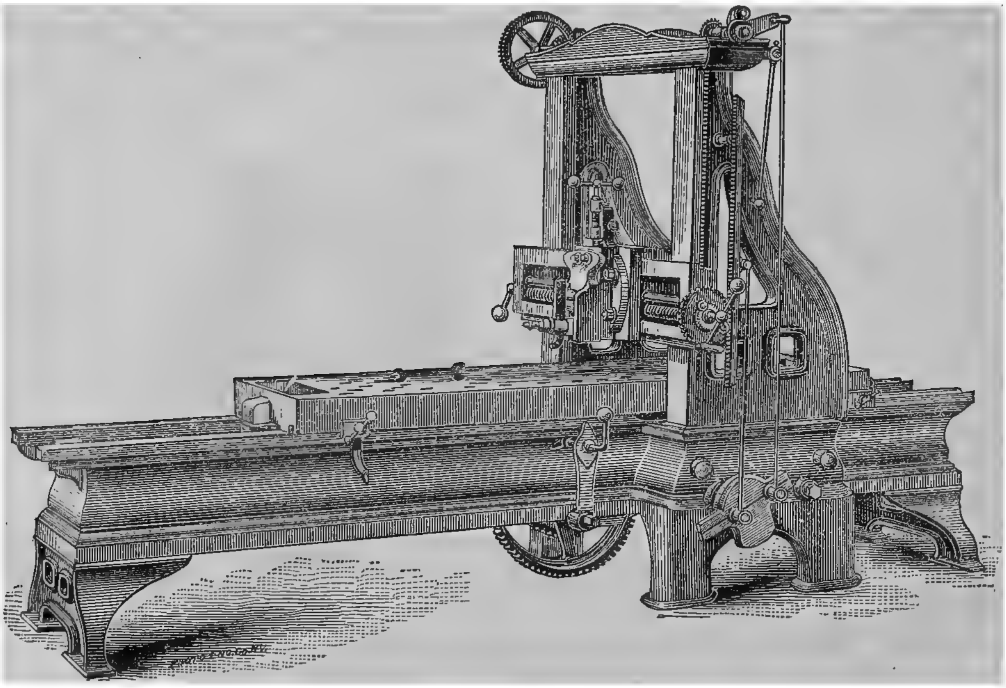


Fig. 232.

object, since the heaviest strain will always be upon the length between supports, and by the use of brackets the legs come nearer together, with a given length of trough. The bed must also be longer than the table, for while it is not necessary that it be twice as long, yet there must be no tendency for the table to tip when loaded at one end. By making the table itself deep the pressure is distributed more uniformly, and the tendency to spring is diminished. The uprights or cheeks have to resist a strain tending to bend them backward by pressure against the cross-head. This pressure will have the greatest leverage when the cross-head is near their top, and therefore the uprights will be of greatest depth and section near the bottom. There has also been great improvement in the design of these uprights with regard to stiffness. The amount of metal and its disposition is much more judicious than in the earlier forms. Openings are made in the cheeks for lightness of their web, considered as a girder, and to enable the operator to look through them at the work. The uprights are bolted very firmly to faced surfaces upon the sides of the bed. They are united by a strong girt at the top. In older practice this was an entablature bolted to the top of the sides. In modern designs the girt is cast as part of the uprights, or bolted to their sides, and is curved horizontally to act as an arched brace, to stiffen further the uprights and distribute an unsymmetrical pressure more equally on both. The uprights are put a little behind the middle of the length of the bed, in order that in front of them may be a clear space for securing and examining work. They are faced on the front side for the bearing of the cross-head, and upon some rear surface to admit of clamping the cross-head by a gib. This

clamping surface may be either an outside flange or one made by a slot down the face, which divides the bearing surface into two parts. The cross-head is upheld and adjusted by two screws, which are coupled together by a horizontal cross-shaft overhead through pairs of bevel-gears. By turning the horizontal shaft by a crank- or hand-wheel the two ends of the cross-head are raised equally at once, and require no repeated adjustment. In the larger tools this cross-shaft is driven by power, usually by a belt-wheel. Since the weight of the cross-head and attachments are opposed to the strain of the cut the screws can be used to reinforce the clamps. After the head is secured in place by the clamping-bolts, an attempt to screw down the screws will take up all lost motion and give extra points of resistance. On account of the necessary play in the number of joints, it is not generally thought judicious to attempt to feed downward by the adjusting-screws. It has been done (Fig. 232), but recent practice

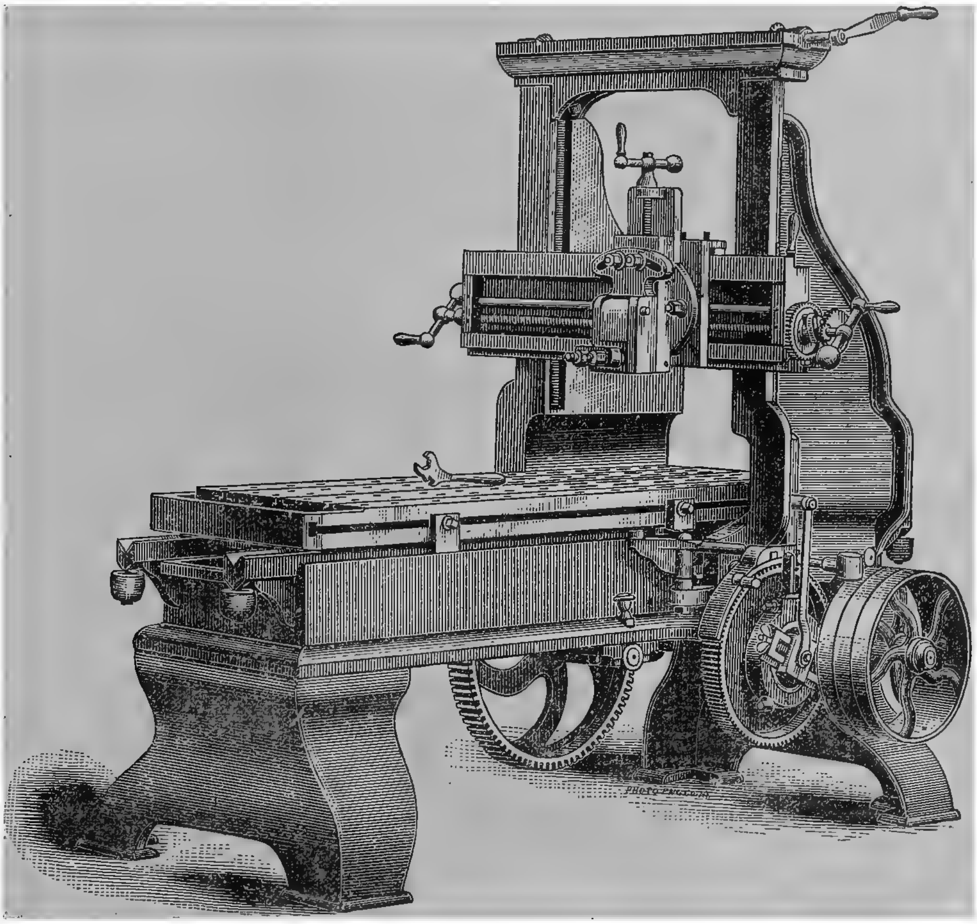


Fig. 233.

prefers to clamp the cross-head, and give all the vertical feeding at the slide to the tool-point and apron. The clamping is usually effected by two bolts at each cheek, which tighten a gib or plate, clasping the faced guide surface of the upright. The lifting-screws are carried either inside the uprights when they are of box-form, or outside of them at the back or sides. In the former case the projecting lugs which form the nuts pass through slots in the upright and serve as guiding-slides. In the latter arrangement the nuts are often separate and are bolted on to the back of the head. The uprights are often arranged so as to carry extra tool-holders (Fig. 248) for vertical surfacing.

The cross-head itself must be straight. It is very often strengthened against flexure sidewise between the uprights by stiffening-ribs at the back (Fig. 235). To lighten the web of its depth, holes are often cored out in the casting in the central part. Since it is designed to carry the slide or saddle which holds the tool stiffly and yet permit the feed-motions, there must be a track or shear planed on the front surface, in order that the saddle may be gibbed to it. These shears appear in three different forms. The upper part is made square, to resist the pressure due to the weight of the saddle (Fig. 233). This embraces the square on the top and front and rear, the top and rear bearing being gibbed to take up wear and lost motion. The under side of the shear is planed to a **V**, sloping inward and upward. In the second form both upper and lower surfaces are inclined inward, and the third form has the upper and lower **V** parallel, the lower face in all cases sloping upward and inward. The first form is by far the most prevalent, though some very excellent designs retain the second. The squared surfaces oppose the strain on them by normal resistances, and therefore move more easily than where there may be a wedging action.

The lower **V** resists the upward oblique strain of the cut, and prevents any jarring by its shape. The gibs are adjustable by screws bearing against them in shallow counterbores, or else they are tapered, and adjustable by screws and jam-nuts.

The front of the track is flat and of sufficient breadth to resist the horizontal pressure. What surface is not required between the top and bottom rail is cut away, and accommodates the rod and screw for the feed-motions of the saddle and apron (Figs. 234 and 235). The saddle fits upon the track on the cross-head, and has a horizontal motion upon it. The saddle is either rectangular, as in the cut, or in more recent practice has wings at the top for increasing the length of bearing surface, thus diminishing wear. Into the back of this saddle is secured a brass nut, through which passes the feed-screw. This screw usually runs near the bottom of the hollow of the rail, and its rotation in either direction will accordingly carry the whole saddle across the table. The front of this saddle-plate is finished off with a boss and a circular **T**-slot, into which bolts may fit, by which a swivel-plate may be

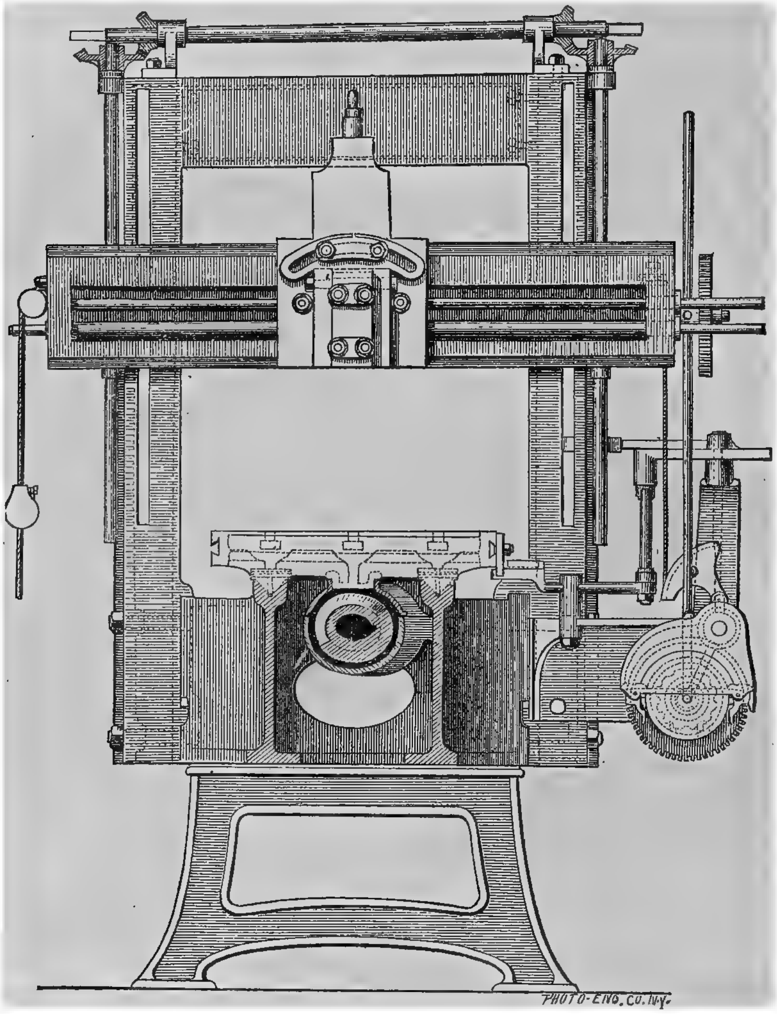
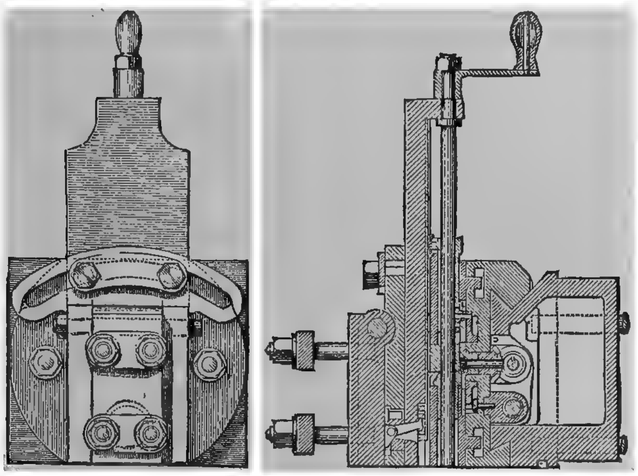


Fig. 234.

secured in any angular position. This swivel-plate carries a second flat shear, planed on its edges to a **V**, sloping inward. Upon this guide is gibbed a slide, to which the tool is secured. The slide is fed along the guide at whatever angle it may be by a screw with ball-handle or hand-wheel. To produce this vertical or angular feed of the tool-slide is the object of a splined shaft which lies along the hollow of the cross-head above the screw. This shaft carries a bevel-gear which drives a short idle shaft of bevel-gear in the axis of the swivel-plate. The third gear turns a fourth upon the axis of the downward feed-screw, so that rotation of the splined shaft will turn the screw of the feed at whatever angle the latter may stand. The fourth gear will roll around the circumference of the third when the swivel-plate is adjusted. The fourth gear may be splined to the angular feed-screw, or it may be made to serve as the nut for the latter. In this latter arrangement, when the automatic feed is in use, the screw must be locked either by a friction-clamp or by a locking-pin. When fed directly, the friction of the splined horizontal shaft is the dependence for holding the nut. In the former arrangement it is not expected that the direct feed will be much used. In fact it is not. Very often in large tools the top of the saddle is out of reach, and in smaller ones the end of the cross-head is more accessible without reaching over the work. The ends of the screw and the splined shaft are squared to receive crank or ball-handle when feeding by hand.

The power-feeds are intermittent, as they should be. The cutter, after being set, makes a stroke with the feed at rest, thus cutting always in lines parallel to the guiding V's. The feed-shafts are fitted at their ends nearest the operator to receive a loose gear. This gear carries a pawl or dog, which may turn a slip-gear in one direction or the other. Motion is imparted to the loose gear through a small angle from a slotted crank, the variation in the amount of feed being caused by greater or less length of crank. A link from the adjustable pin of this crank gives



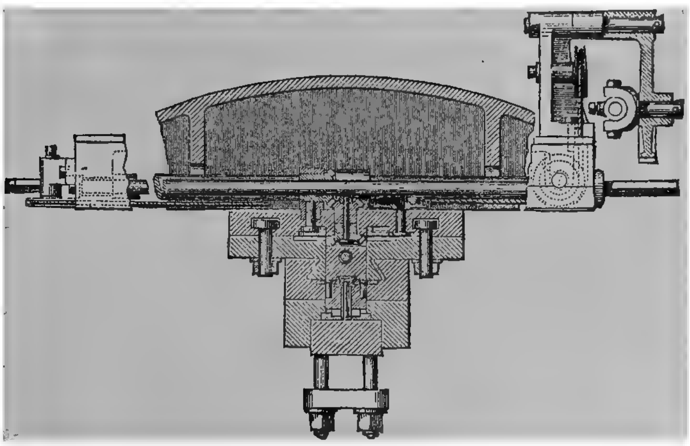


Fig. 235.

an alternating motion either to a rack, which thus turns the loose gear, or else to a sector, which acts similarly. The reason for the use of the rack is that thereby the cross-head may be at any elevation and yet the feed mechanism will be always in gear without adjustment from the operator. Where the sector or its equivalent is used, the link which moves it is clamped to it by a short set-screw, which must be loosened when the cross-head is to be reset.

In the type shown in Fig. 236 the adjustment for height is permitted by the vertical shaft with a spline. Motion is imparted to it by partial bevel-gears. The reason for using geared transmissions is that if jointed linkages were used the leverage of the ratchet would be continually varying, and a coarse feed would be impossible with a compact arrangement and short levers. The slotted crank, from which motion is received for the actuation of the pawl, should be made as part of a wrist-plate, so that the pin in the slot may be on either side of the center of motion. This is necessary, because the stroke of the link in which the pawl slips over the teeth of the wheel must always be made at the end of a cutting traverse of the bed. Otherwise, before the return of the bed under the tool the feed for the ensuing cut would have been made, and great wear of the cutting-edge would ensue. Hence the acting stroke of the feed must be on the lifting or falling stroke of the dog according as the feed of the tool is in one direction or the other. There are but few tools which do not permit this adjustment.

This alternating motion for the feeds is either received directly from the driving mechanism or from some of the levers which control it and make it automatic.

The earlier driving mechanism consisted of a screw in the middle of the bed, whose long nut was made part of the table. The screw was square-threaded, of quite steep pitch, and was turned at one end by bevel-gears from a transverse shaft. These gears had to be small, in order that the rear end of the table might pass over them when planing long work. To effect the quick return of the table on the stroke when the tool was not cutting the

screw carried two bevel-wheels of different diameters, driven by two others of corresponding diameters, whose axes coincided with that of the transverse shaft and were on different sides of the axis of the screw. Of these latter bevel-wheels one was keyed to the transverse shaft, and turned the wheel of largest diameter on the screw. This was driven by the outer belt-wheel of three equal wheels, which was keyed also to the transverse shaft. The

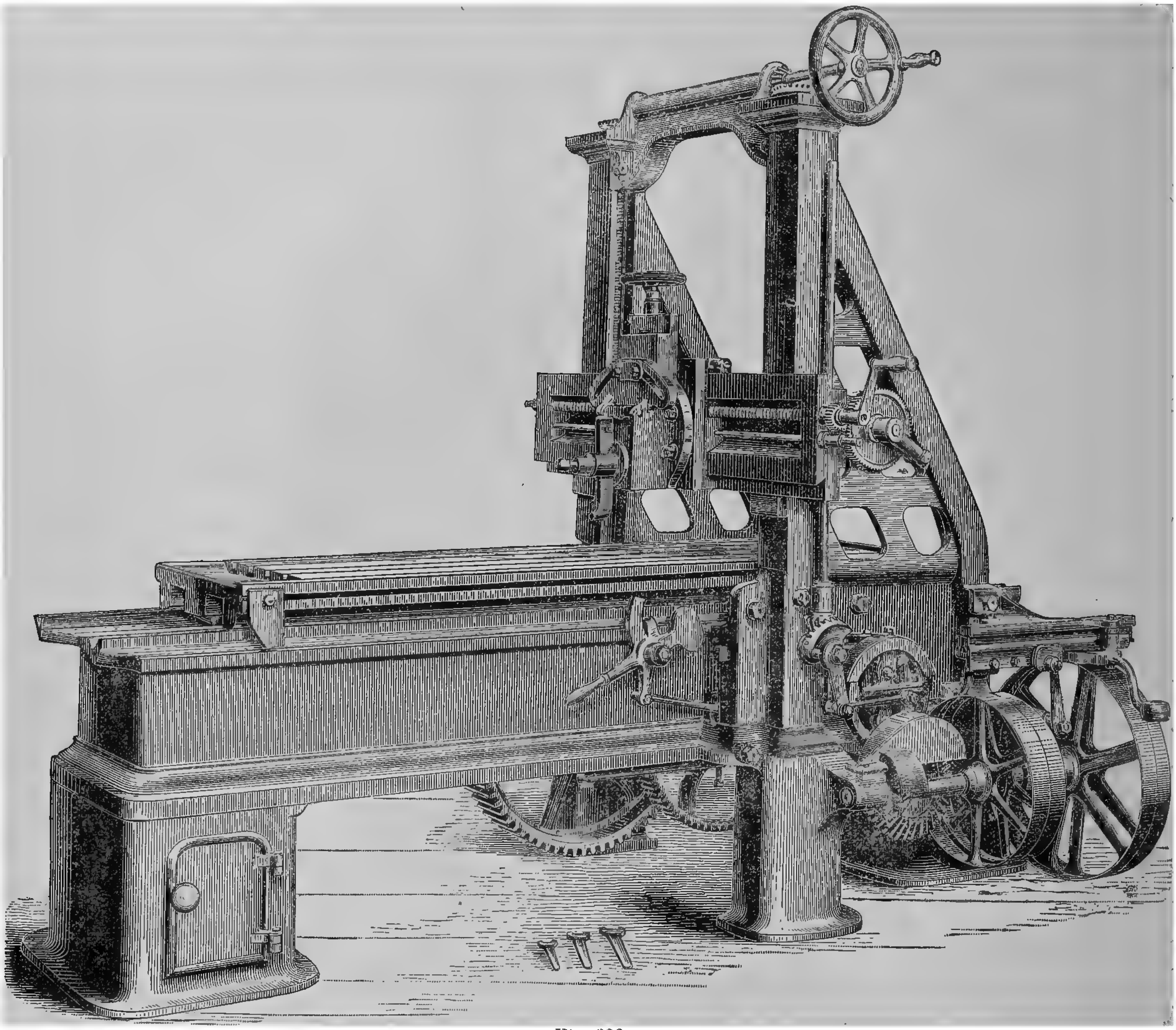


Fig. 236.

other bevel-wheel geared into the smaller wheel on the screw, and instead of being fast on the transverse shaft was secured to a sleeve, turning freely upon the shaft. To the sleeve was also secured the inner belt-wheel, while the intermediate third wheel was loose. It will be seen that while the driving-belt was on the outer wheel the screw would turn slowly with leverage for the cut. When the belt was shifted to the inner wheel, the screw would turn faster and with less leverage in the opposite direction, thus producing the quick return. The idle loose wheel is necessary that the belt may not be upon two pulleys at once which move in opposite directions. The shifting of the one belt from one pulley to the other was effected (and still is) by a pair of dogs or chocks, which bolt at any point in a T-slot planed in the side of the bed. These dogs strike an arm, which gives the transverse motion to the shifter-eyes by a bell-crank. The inertia of the moving bed, coupled with the high speed of the belts, renders the stalling of the machine with the belt on the loose pulley practically impossible. In place of the screw of the earlier types modern practice approves a rack in the middle of the table, driven by a spur pinion. This rack, in the best practice, is cut out of the solid. In the smaller tools it is a plain rack with linear teeth. Some of the larger use a rack and pinion with V-teeth. The object of this is to gain the advantage of strength which comes from large circular pitch, while securing the smoothness of motion which comes from smaller circular pitch and greater numbers of teeth. Something of the smoothness of helical gearing is obtained without the sidewise thrust which they produce. Any sidling is counteracted by the convergence of the lines of each tooth. The

pinion which drives the rack is driven by a train of gearing from belt-wheels. This train will differ according as one or two driving-belts are used in any one type of arrangement, and they will also differ in the arrangement. The most usual arrangement consists in a train of spur-gears, by which the velocity is reduced from that of the belt-wheels. The gears are heavy and are cut. Some are using steel castings for this train. The disadvantage of this system is that the long dimension of the tool is at right angles to the line shafting of the shop, while all the

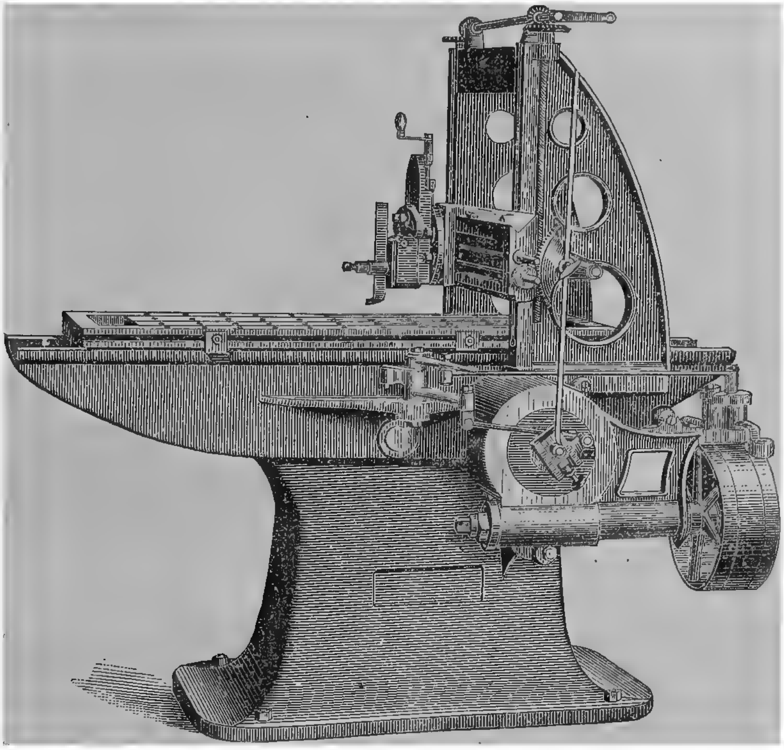


Fig. 237.

lathes are parallel to it. Hence the planers of this type are wasteful of room in a crowded shop. To counteract this difficulty the first transmission from the pulleys has been made by bevel-wheels, the other gearing being the

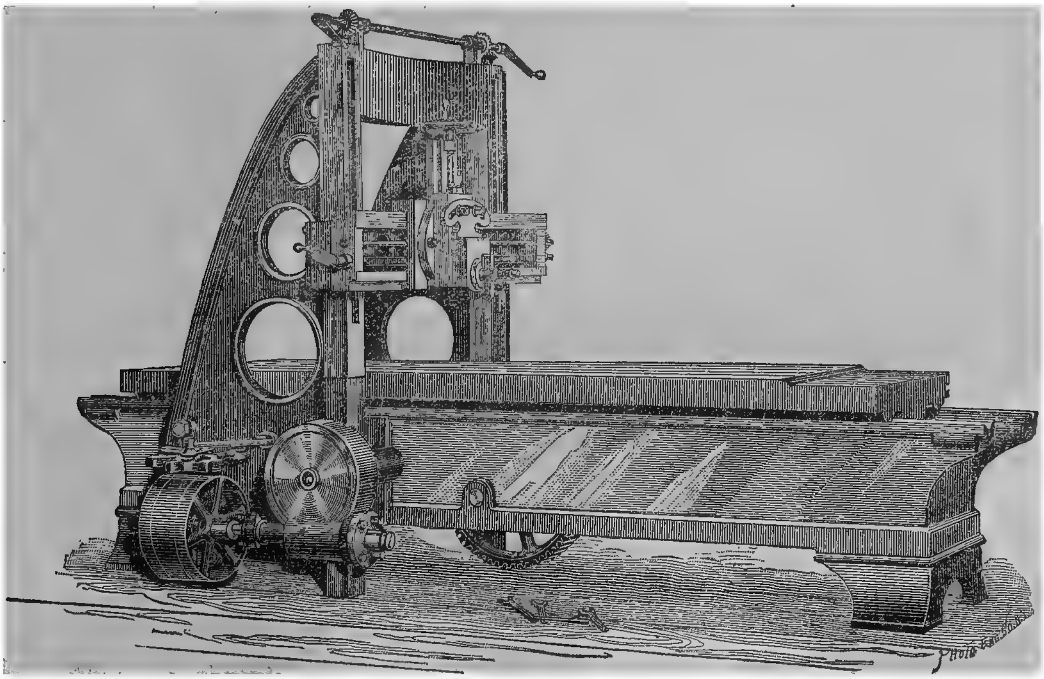


Fig. 238.

same (Fig. 236). This brings the planers parallel to the lathes. Another arrangement uses a worm and wheel at the first corner (Figs. 237 and 238). In still another the rack is driven by a worm of four threads, which has

been called a "spiral pinion", and gears the worm-shaft to the belt-wheels parallel to the bed by a pair of bevel-gears of great difference of diameter (Fig. 239). This arrangement is inferior to the one just preceding, in that

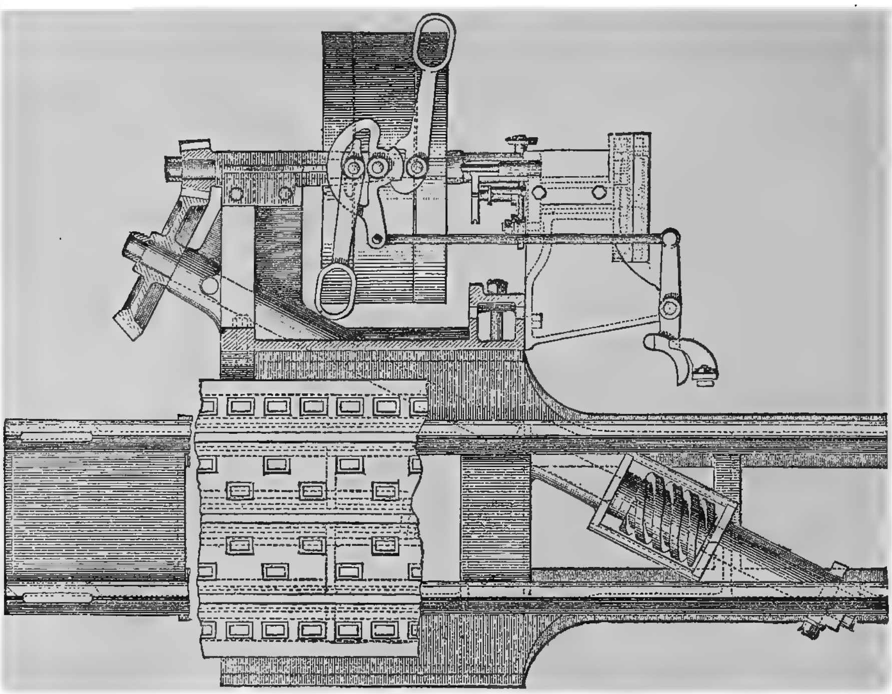


Fig. 239.

the rapid reduction of speed due to the worm takes place after the toothed gears, instead of before. The slower the gears revolve the less noise, chatter, and wear. To accomplish the quick return on the inoperative stroke of the table with two belts is comparatively simple. The usual ratio of quick return is about as one is to two; the return is twice as fast as the cutting traverse. Upon the counter-shaft above the tool are two pulleys whose

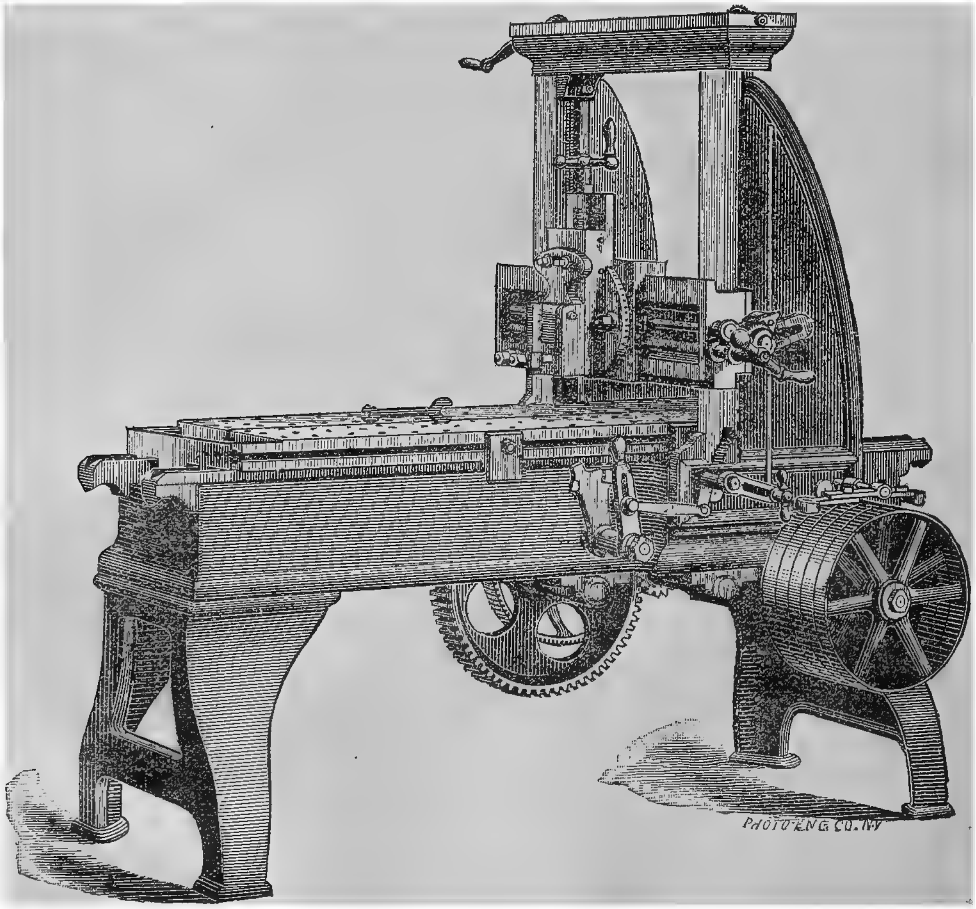


Fig. 240.

diameters are as one is to two. From the smaller one comes the belt for the forward stroke to the pulleys on the machine, while from the larger comes the belt for the return. This belt is crossed or open, according as the other is open or crossed, as determined by the shafting of the shop. The pulleys on the machine are of the same diameter usually. Where both belts are shifted at once, as in some of the smaller planers (Fig. 240), there must be five of them, the two outside and the middle one being loose. This has the advantage that the tool may be stopped without arresting the counter-shaft. On the other hand, the motion of the belt-shifters must be greater. When one belt is shifted upon the loose pulley before the other is shifted upon the fast pulley, as in the newer and better practice, but three pulleys are needed. A wide fast pulley turns between two narrower loose ones. The shifters prevent both belts from getting at once on the driving-pulley, and the shrieking of the belts as they slip in arresting the motion of the train is, to a great measure, avoided. One design has pulleys of different diameters on the machine, by which system four will be required, the two inner pulleys being loose. The system of two belts has an advantage over that using but one belt, in that the train of gearing under the machine is made simpler. Where but one belt is used, the outer wheel will be on a shaft connected to the rack-pinion by a train of gears consisting of an even number of wheels, with large reduction of velocity. The inner wheel will turn loose on the first shaft, and will be connected to the rack-pinion by a train with less reduction of speed and containing an odd number of wheels. When, therefore, there is an odd or an even number of shafts between the belt and the rack the one belt will move the table forward or backward. A loose pulley must separate the other two; therefore the tool may be arrested without stopping the counter-shaft. But the shifting-motion must be ample. Sometimes, to prevent very wide shifting of wide belts on larger tools on this system, two narrow belts were used, four pulleys were required, and each belt was shifted over only one-half the width of the wider belt which would have been required. One form of planer was made in which the reversal and quick return was effected by using external spur-gear from the inner wheel and internal gear from the outer. The internal gear moved the table in the opposite direction from that due to the external, and the speed was changed by the ratio of diameters.

For shifting the two belts in that system at once simple eyes or forks embracing the belts are secured to the rod which receives the cross-motion. For shifting them in succession a variety of devices are in use.

Fig. 239 illustrates one system in plan. There must be a separate shifter for each belt. These are pivoted near the end which is farthest from the belt-eye, in order that a small motion of the shifter-lever may move the belt over a larger distance. The link from the lever, which is moved by the dogs on the table, is attached to a lever vibrating horizontally around a fulcrum-pin. This lever has a tooth shaped on one side, which engages in a space formed in the side of one shifter. This tooth is so shaped as to move the shifter, and after escaping the corner of the space to lock the arm from moving. On the other side of the fulcrum is milled out an internal tooth or hollow cam, which acts upon tooth-like projections upon the other shifter. These profiles are so located with reference to each other that on both forward and backward stroke the belt which has just been in action shall be shifted first upon the loose pulley. Otherwise, large belt-motion would be required.

Another device is shown by Fig. 241. It depends on the principle of crank-motion that the piston moves most rapidly when the crank is at right angles to the axis of the rod. The two shifters are connected by links to pins on a horizontal wrist-plate which are on radii about 90° apart. The wrist-plate receives a partial rotation from the shifter-dogs, and always stops so that the pin connected to the belt which is driving shall stop with its radius perpendicular to the link to the shifter of that belt. By this expedient, for any angular motion of the wrist, the driving-belt will be shifted farthest at first, and may be off the fast pulley before the other is moved on.

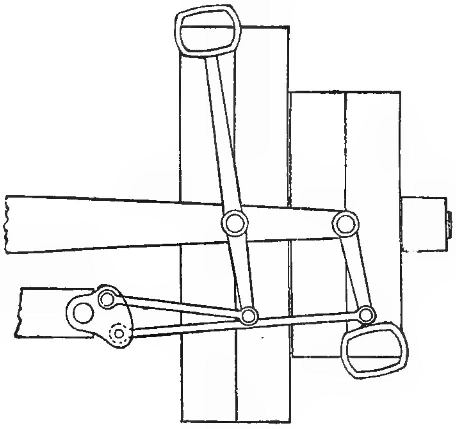


Fig. 241.

Another device has a vertical pin upon the tail of each shifter, which is moved by a groove in the lever from the shifting-dog. This groove is so designed that the pins shall be moved successively upon each reciprocation of the lever (Fig. 245).

In another design a slide receives a motion greater than that required to move the shifters. Truncated pyramids on each side of the slide engage with the double rocking tails of the shifters. The excess of motion of the slide causes the motion of the shifters to be successive, and the upper bases of the projections lock the tails of the latter. In another device the sliding-plate from the dogs has two inclined grooves in it, which operate pins on the shifters.

The planer shown in Fig. 242 adopts a principle different from any of the foregoing. There are two pulleys loose on the spindle. The middle wheel is a double-friction clutch, which may be engaged with either wheel by a slight longitudinal motion, so that the arbor will be turned either by the open or the crossed belt and at the suitable speed. The clutch is moved by a pin on a sleeve upon which turns the inner belt-wheel. This pin receives its motion from a slot cut diagonally in a short sleeve. This sleeve is rotated on its axis by the table dogs, which rotation causes the pin to slide up or down the incline and to throw the clutch in one direction or in the other. This arrangement causes the reversal to be very quiet and instantaneous.

To insure that the shifting devices shall receive equal motion on both strokes of the table the two dogs are often made to strike the levers at different points. The table has less momentum on the cutting-stroke than on the return, since it is moving more slowly. Hence the dog for the motion on this stroke is often made longer, so

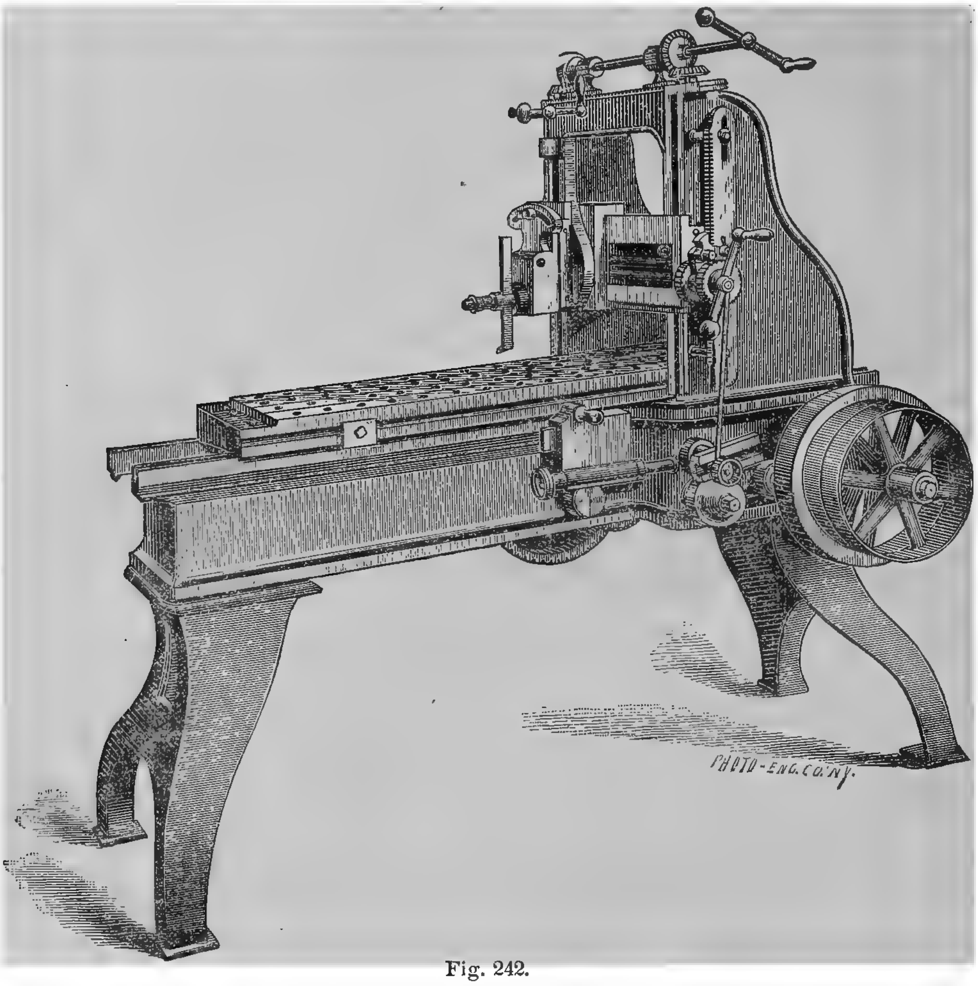


Fig. 242.

as to strike the shifting-lever nearer the center of motion. This will give the same ultimate motion as when the shorter dog of the return traverse moves a greater distance nearer the end. The end of the lever which is moved by the dogs is often arranged with a spring latch-gear, so that the latch may be sprung out of the path of the dog and permit the table to traverse farther than the limit for which the dogs are set (Figs. 237 and 243).

Without this convenience it is necessary to unscrew the dogs when the operator wishes to examine the work in front of the cross-head and tool and to set them anew when the cuts are to be resumed. The shifting-levers have usually a handle for their convenient manipulation by hand.

To obtain the single reciprocating motion required for the feed-motions in all directions is a simple problem. It is solved in two general ways. The motion is either taken directly from the levers which are moved by the table-dogs, or else it is taken from the train of driving-gears by a frictional device. This latter system is perhaps more general than the other, but it may be questioned whether it is preferred for any very cogent reason on small tools. The shifting-dogs and levers should be stout enough for their own duty, to be able to withstand the slight extra strains for feeding. The feed has only to overcome the friction of parts, since there is no cutting strain on the tool when the feed is given, and therefore the shifting-motion may be multiplied, if desirable, to have a capacity for a coarse feed for finishing. When the feed is taken from the train one of the arbors (usually the second) is prolonged outside the bed. Upon this arbor is secured a cast-iron disk, and a second disk compresses a loose washer of leather against it with any desired pressure. This pressure is made adjustable by a screw and nut. The second disk is loose on the arbor, and carries on its face the slotted crank, from whose pin the reciprocating link passes to the ratchet-gear. This loose disk is caused to revolve by friction of the leather, between stops, which permit the crank to make one-half of a revolution at each change of direction in the motion of the train. This also insures that the feed shall be given before the cut begins, and any desired power of feed may be secured by the frictional compression of the leather. The disadvantage of this form lies in the slipping of the disks while the movable one is held against the stops. This consumes a little power, and wears the disks.

Another form (Fig. 245) uses the friction due to compression of a wrought-iron split ring on the periphery of a disk. The ring is split, and is compressed by adjustable springs on the outside. An elliptical pin is fitted in the

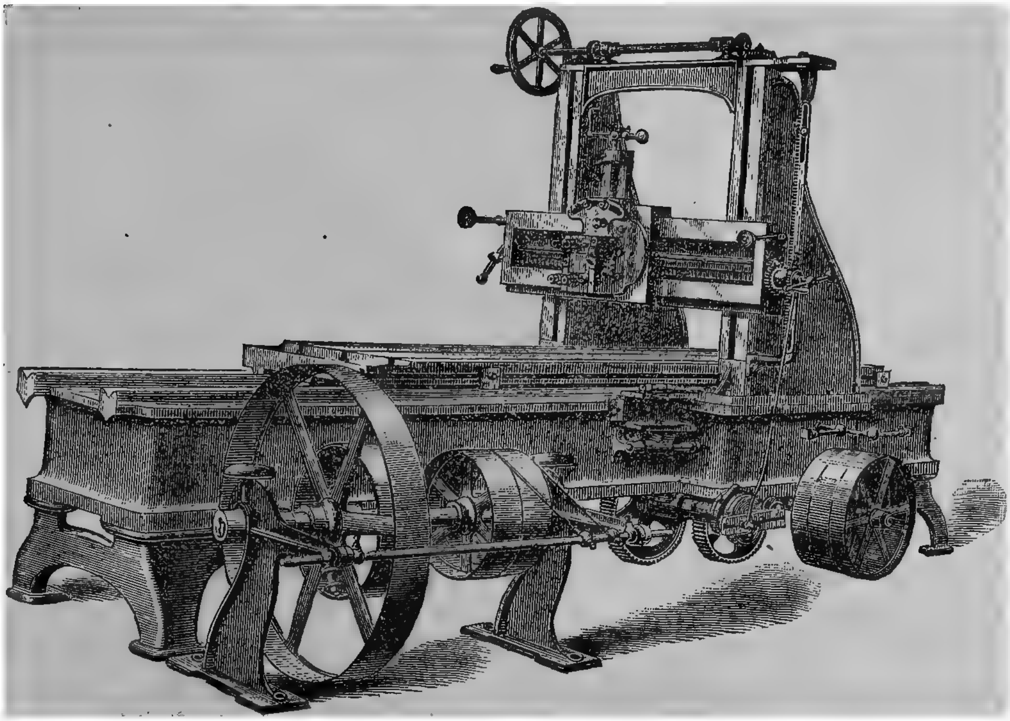


Fig. 243.

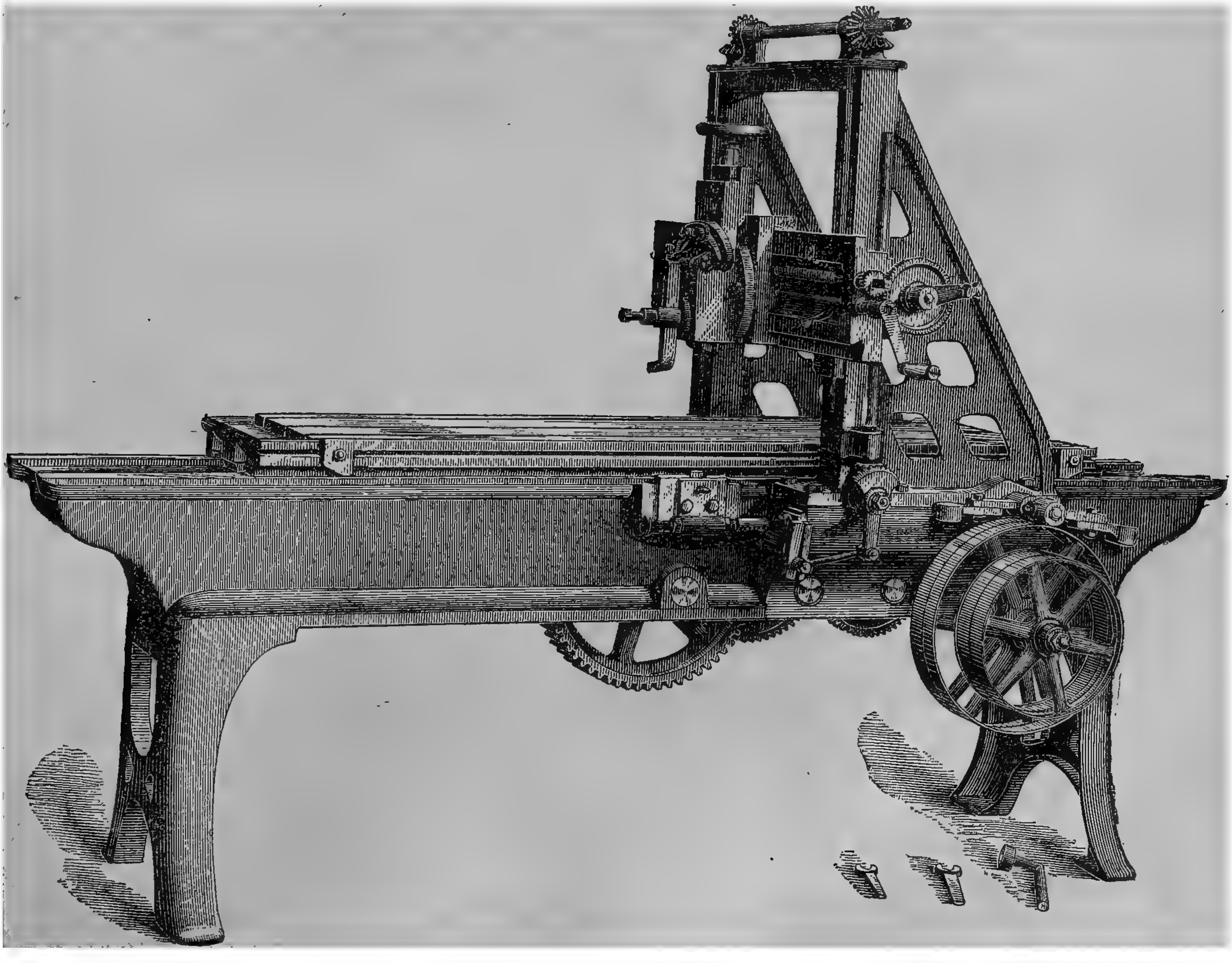


Fig. 244.

split of the ring, which is of such dimensions that the long diameter shall be sufficient to open the split and release the ring. The short diameter of the pin is enough less to permit the ring to close and establish the friction when the former is turned less than one-half around. It will be sufficient to cause the stops to turn this pin partially when the feed is made. The friction will be in a great measure released as soon as the stops are reached. A similar type is shown by Fig. 233. The friction will be engaged by the spring of the ring, when a stop no longer opposes it.

The device of Fig. 246 uses friction only to engage the pawls at each change of motion. A positive motion of the crank-disk is kept up by the ratchet-wheel until the pawl is disengaged by a positive stop. The ratchet-wheel is revolved by a pinion on the front end of the pulley-shaft.

In the planer shown in Fig. 236 the feed-motion is positive from the train, without the necessity of friction devices. A pinion on the second arbor of the train turns a half-wheel. The pinion and wheel may be toothed, or

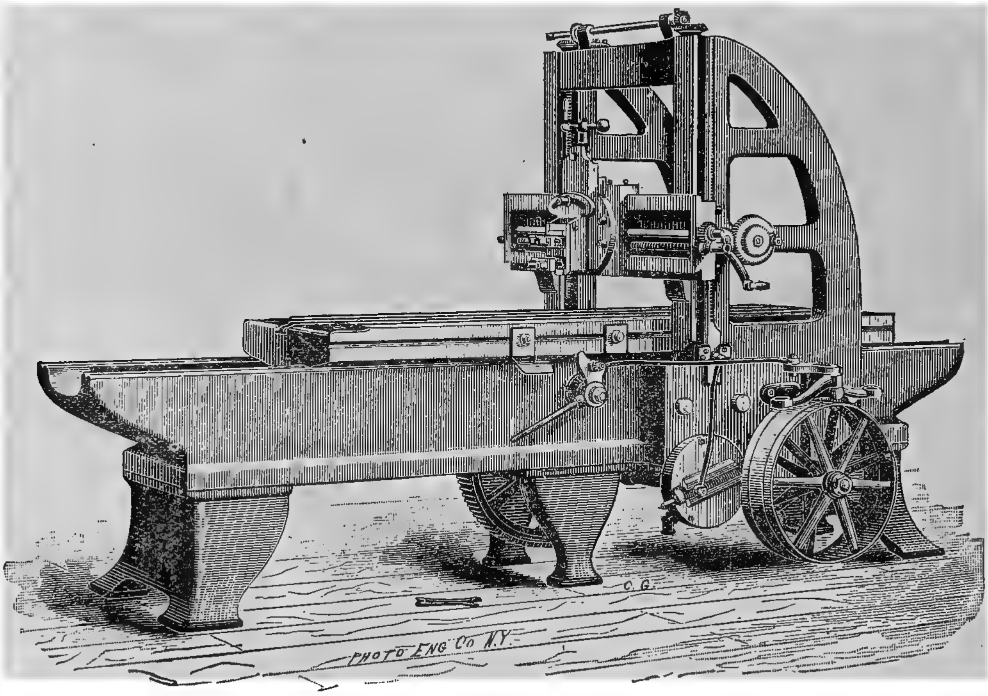


Fig. 245.

in newer practice are made of **V**-friction faces. The semicircle of the wheel is counter-weighted, to preserve its equilibrium. The face of the pinion is broader than that of the wheel. The last three-fourths of an inch of the face of the latter at the two ends of the semicircumference is arranged so as to be effective at the *beginning* of the half revolution, but inoperative at the end. This is accomplished by making this last fraction of the face at each end to be the end of a dog, which swings from a stud on the plate of the wheel and abuts in one direction against a stop. When the pinion on the train reverses, the dog engages with it, and by pulling against the stop the face is drawn into gear. At the end of the half revolution the dog clicks idly over the pinion, until its

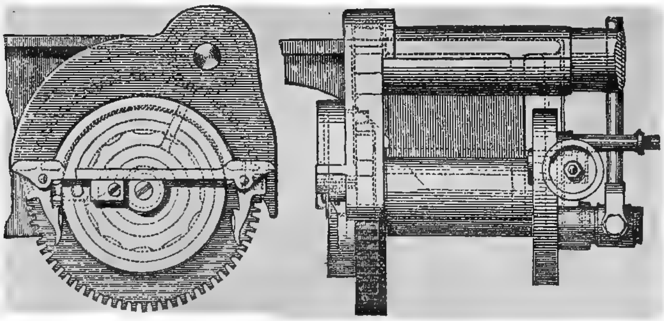


Fig. 246.

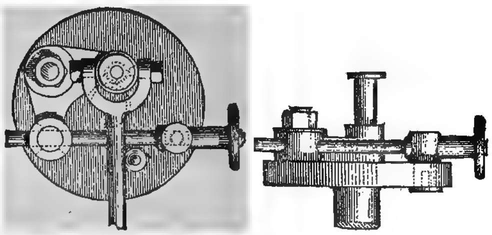


Fig. 247.

direction changes. With friction faces this clicking is noiseless. For the adjustment of the amount of the feed, while the tool is in motion, the pin on the wrist-plate is either clamped by a hand-nut or else is upon a screw. By turning this screw the pin traverses in the slot, and by it may be held at any distance from the center.

A very ingenious device for this object is illustrated by Fig. 247. The milled head on the post will move the upper end of the pivoted bell-crank, by which the pin of the vertical link will be moved and clamped nearer or farther from the center of the motion of the disk.

Were the tool held rigidly at the slide-rest, the return of the work under it would scrape the cutting-edge from behind and dull it. Hence all tools, both light and heavy, have the tool secured to a swinging apron, hinged on a conical pin between cheeks on the slide. This permits the tool to swing outward upon the return of the work, and where the tool and apron are light this arrangement is sufficient. On larger machines, with heavy cutter and

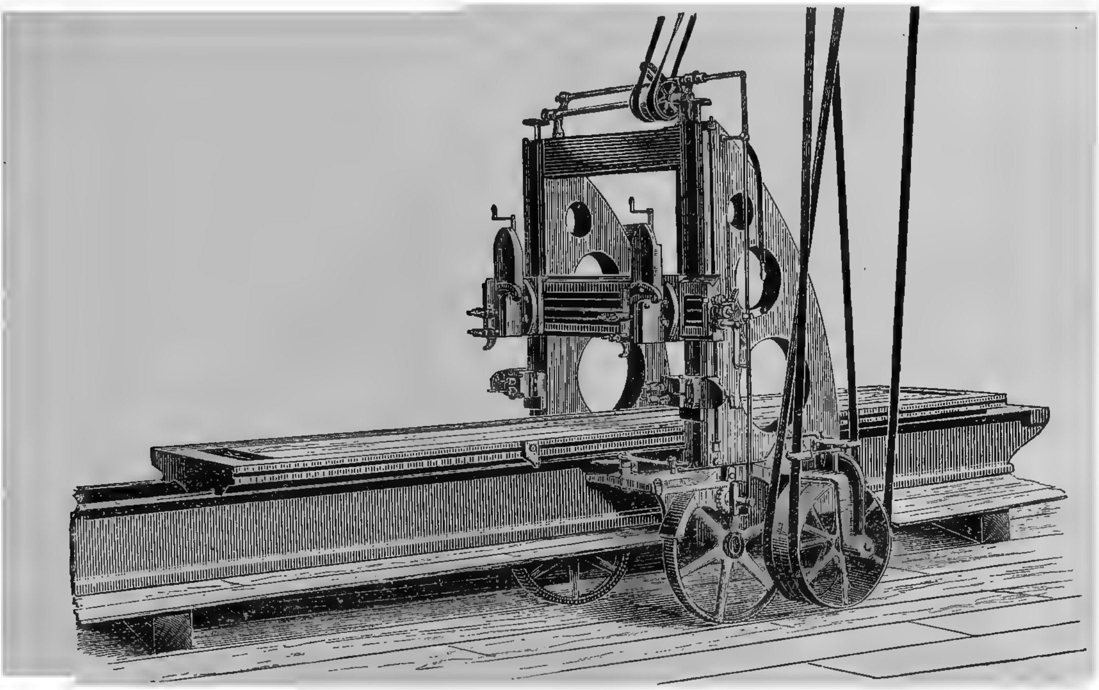


Fig. 248.

apron, the weight of the combination will be sufficient to press the edge with a grinding pressure against the work. It becomes necessary, therefore, to lift the apron and the tool by positive means. There are several methods of

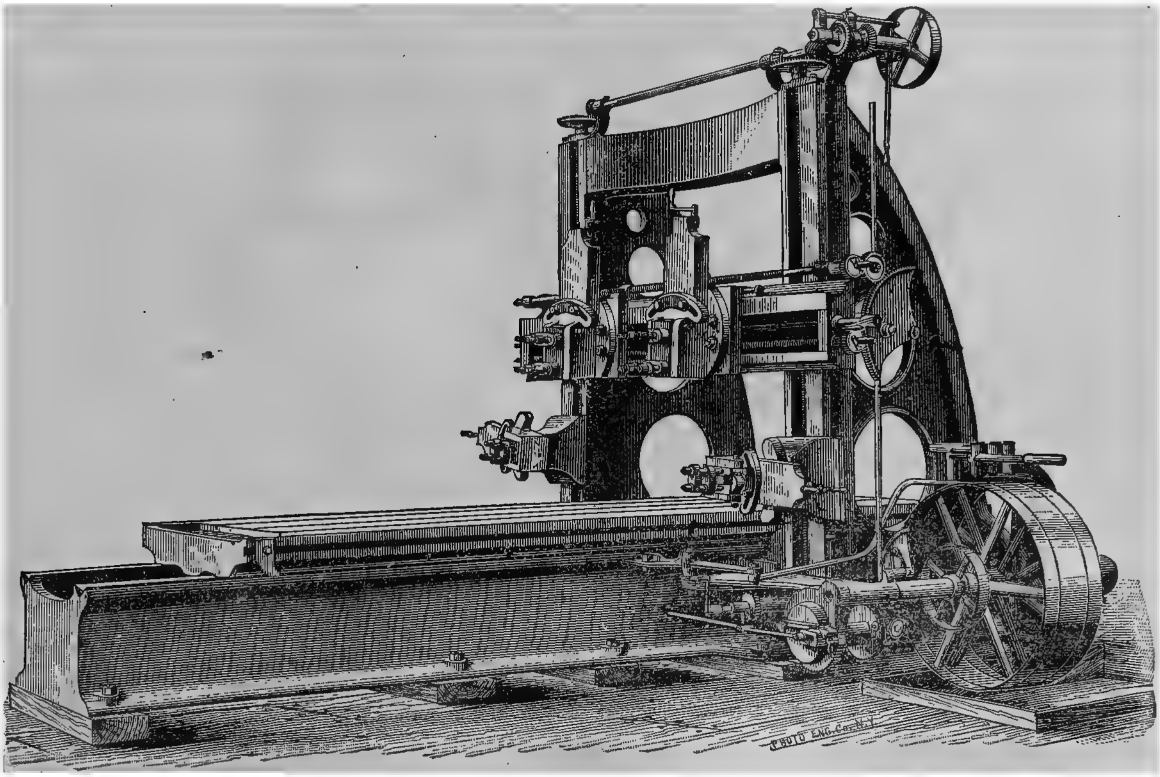


Fig. 249.

effecting this, but all use a cord over pulleys pulled by the feed-levers and kept taut by a weight. The feed-lever pulls on the cord and turns a spiral washer under the apron. The rise of the inclined plane against a twin washer

in the bottom of the apron throws the tool forward and up. When the feed-lever reverses, the weight rotates the washer back into its first position. A second arrangement makes the cord lift a knee-lever against the apron by the rotation of a disk or washer with eccentric hole. Still another has a cam on the end of a vertically-oscillating lever. All accomplish the purpose about equally well.

Planers of very large size will have two slide-rests on the cross-head, and an extra rest upon one or both of the uprights (Figs. 248 and 249). An extra feed-rod will probably be required for the second rest on the cross-head, but the rests on the uprights are usually arranged for hand-feed only. These larger tools, being designed for work of great weight from which a heavy chip is to be taken at each cut, usually move more slowly than the lighter tools, and have more wheels in the train which drives the table. The feed also has to be powerful, and the cross-head and rests must be located by power.

Fig. 249 shows the device for lifting and lowering the cross-head by two bevel-wheels, which may be clutched to the shaft of the overhanging belt-wheel to produce motion in either direction. These larger tools are usually built with the rack with **V**-teeth. In these longer trains of gears there is more chance for back-lash in the teeth, which produces, with the elasticity of the belt, a disagreeable intermittance of the motion of the table, which is fatal to the exactness of some work. The design of Fig. 249 drives the table through one pair of gears and the worm which meshes into the rack. The smoothness of the worm-motion is noticeable, and the obliquity of the passage of the worm-shaft through the bed-casting prevents the weakening of the bed by its being cut open to admit of the

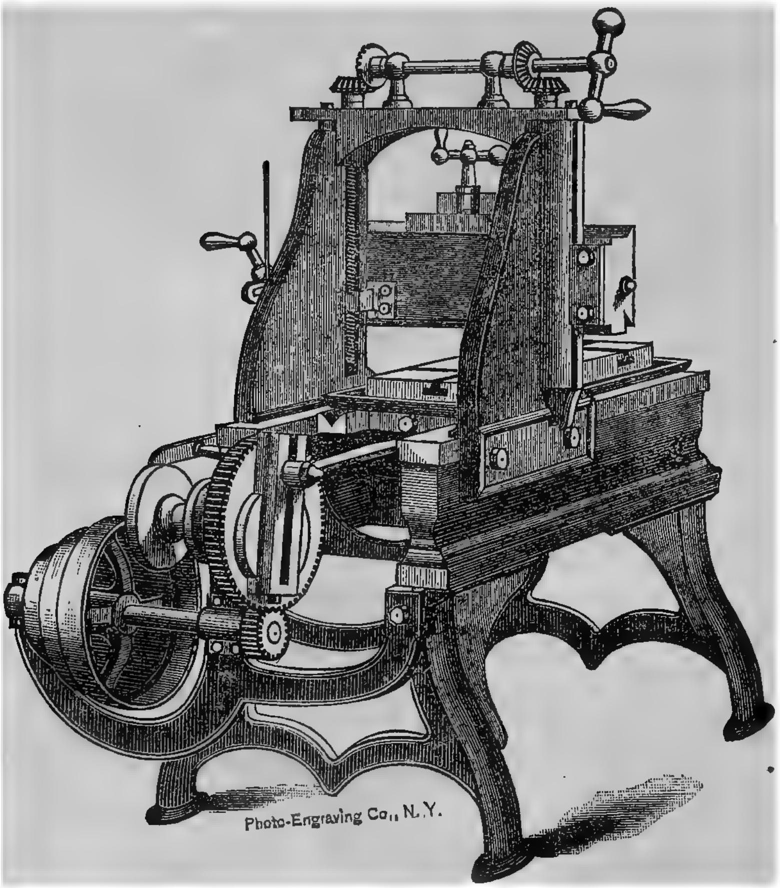


Fig. 250.

gear-train arbors. The rack-teeth are straight, but inclined at about 5° to prevent a tendency to sidewise motion. The thrust of the worm-shaft under the cut is borne by a step-bearing in the rear side of the bed, and that of the quick-return motion by hardened steel collars. The other features are common to the smaller designs of the same builders.

For small work, where the speed may be increased, a great deal of work can be satisfactorily done upon crank-planers. The bed stands high upon legs, and instead of being driven by screw or rack, it is reciprocated by a slotted crank on the cone-pulley shaft. The stroke is adjusted for length by the position of the crank-pin, and for speed by the cone-pulleys. This adjustment of speed is made necessary by the fact that without it the table would move over its travel in the same time, whether the stroke were long or short. This would make the cutting-speed to vary between too wide limits.

The crank is either of the ordinary form, or else of the Whitworth quick-return type, which is employed for shapers (Fig. 250). This latter device results in a saving of time. The tool is usually fed by power for horizontal

traverse only, from a groove in a cam-plate. The design of Fig. 251, however, presents all the conveniences of the larger tools. The connecting-rod eye is held in a slot in the under side of the table in these tools, its position being adjustable by a screw in front.

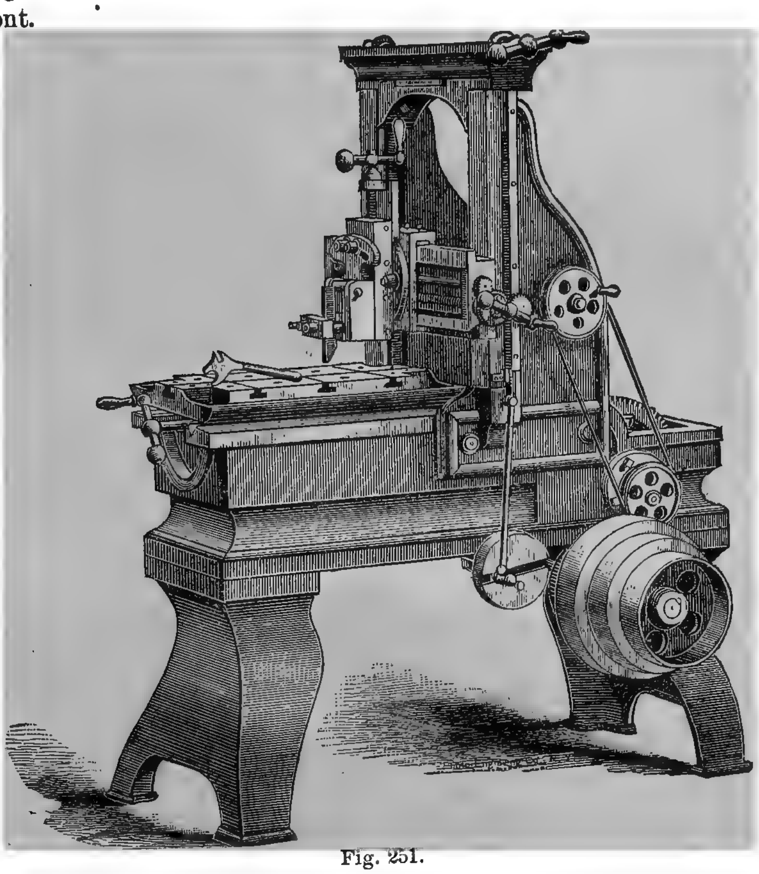


Fig. 251.

This class of machine is much used for brass work and the like, presenting some advantages over the ordinary type of planer, or the shaper, which it much resembles.

§ 27.

SPECIAL FORMS OF PLANER.

To save at least one-third of the time of planing operations as usually done, planers have been devised with two cross-heads. These are held upon two sets of uprights, which may be bolted in T-slots on the side of the bed. Both may be made adjustable (Fig. 252), or only one (Fig. 253). The former shows a novel device for feeding the

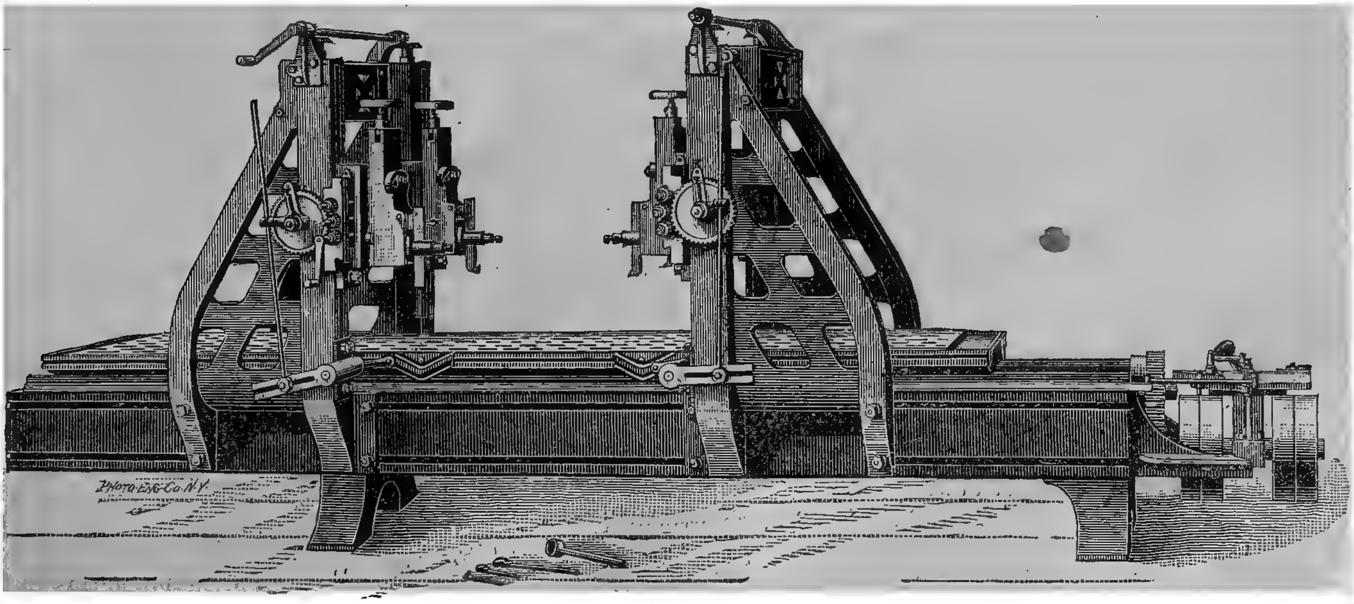


Fig. 252.

slides, and the two designs differ in the method of applying the principle of the screw for driving the bed. Each is driven by two belts. These tools are especially adapted for planing the stubs of engine-work or for other short surfaces upon long work. At least two articles can be finished at each end at once.

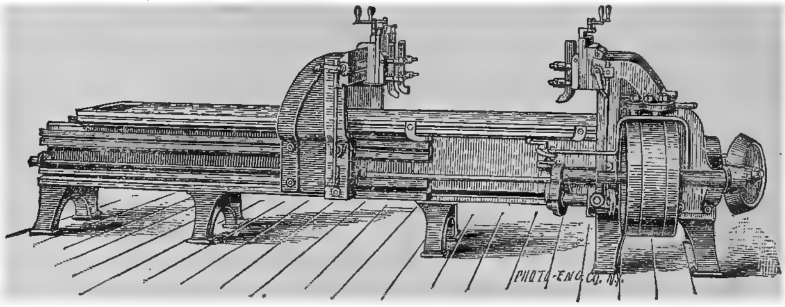


Fig. 253.

Figs. 254 and 255 show two types of machine for edge-planing of boiler- or ship-plate for calking. If not so treated the calking edge must be produced by hand-chipping, which is costly, and will not be so exact. The plate is held stationary by the long vise-jaw in Fig. 254, the two screws at the ends being worked together by the hand-

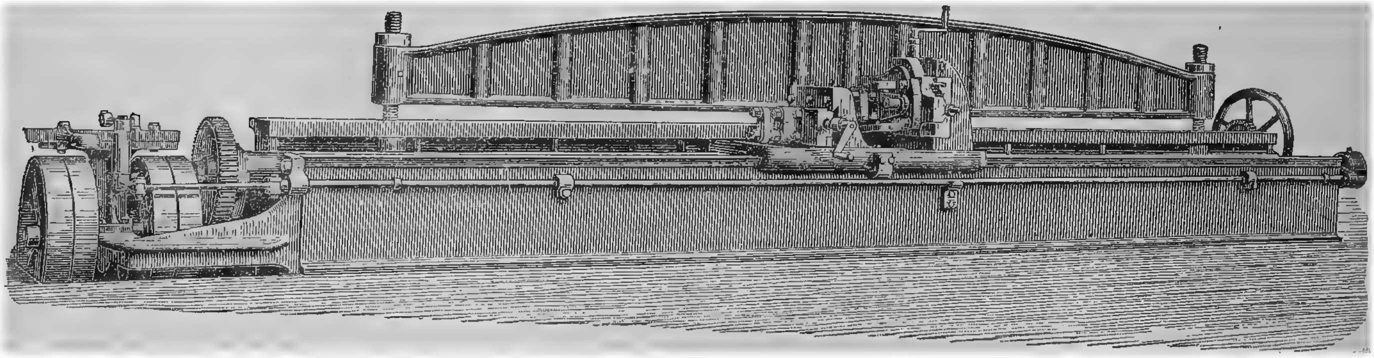


Fig. 254.

gear at the right. Bosses for set-screws are provided in the movable jaw, in case ship-plates are to be beveled after being curved. The other design clamps all work by the set-screws. The tool-carriage is fed by a long screw from open and crossed belts. It is intended to carry at least two tools, and sometimes three. Where two are used one cuts on one stroke and the other on the return. Where three are used, two cut on the forward stroke and the third makes a finishing cut upon the return. This latter has a stop provided, so that when the holes are arranged at first to be parallel with the future edge, all holes shall be at the same distance from that edge. These tools will plane plates 14 or 15 feet in length.

For special purposes attachments may be applied to any pattern of planer. One builder of large engines has applied a boring and facing attachment to his largest planer. By this means engine frames may be planed for the guides and trued at the cylinder ends with one chucking to the table. Locomotive-shops have applied false tops to the tables for planing the links of the reversing and cut-off gear on the Stephenson system. The link has a curvature due to the radius of the eccentric-rod. The link may be clamped to a vise which swings around a center in a line at right angles to the path of the tool, and at the proper distance from the center line of the slot. In another and simpler device a slotted bar bolts to the rear of the cross-head. It projects horizontally at an angle, and a slide on top of a post fits the slot in the bar, and gives the proper rotating motion to the false top.

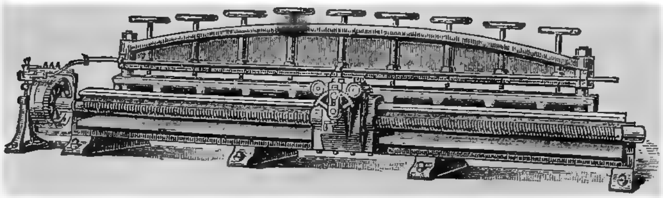


Fig. 255.

The frames and table of planers are often used for the foundation of other machines working with rotary cutters, to which allusion will be made in the sequel. For some special work on locomotive-frames an unique planer has been made, with one upright at the working side as usual, but having the other end of the cross-head carried by an arched frame. This frame is made of open cast iron, in somewhat the form of an arch. The abutments are at the ends of the bed, so that wide work may overhang the table of a smaller planer at the farther side. There are but three or four of them in use.

§ 28.

SHAPERS.

The term shaper is applied to a tool in which the planer principle is inverted. The work is held and the tool traverses across it while feeding-motion is imparted to either or both. The tool is held at the end of a long slide, which receives a reciprocating motion usually from a connecting-rod and crank. This slide is guided by a track or shears, to which it is gibbed, and is made long to resist the increased strain when working on a long stroke with considerable overhang. The tool has a quick return in most cases, either by the Whitworth gear by two elliptical wheels or by two belts from wheels of different diameters.

The principle of the Whitworth gear is shown by Fig. 256. A gear-wheel, S, is driven by the small pinion. The crank-body P does not have the same center as S, but is eccentric to the latter. Its center is C. The center of S is made large enough for the center C to pass through it, as shown by the dotted line. The crank P is not connected to the face of S, but may slide upon it as it is compelled by their mutual eccentricity. The rotation of S, however, compels that of P by the pin in the face of the former which plays in and out in a slot in the tail of the latter. Hence, when the pin is farthest from the center C, the slide connected to R will move most slowly with

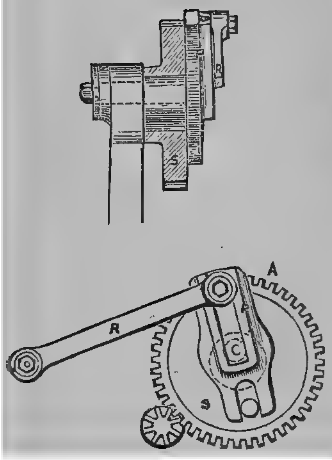


Fig. 256.

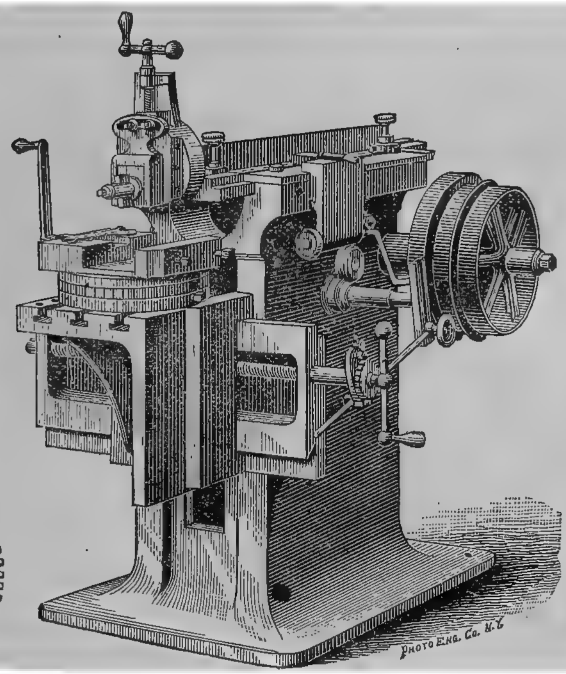


Fig. 257.

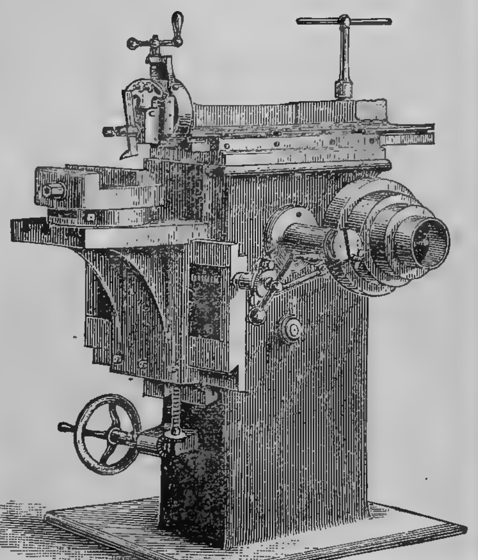


Fig. 258.

the greatest power. When the pin is nearest C the crank will turn most quickly, but with least force for the return stroke. The variation of stroke is accomplished by the slot in the crank-arm. To compensate for the higher speed of long cuts the small pinion is driven from cone-pulleys. In the elliptical-gear arrangement the wheels are horizontal, and turn around their two foci. The quick return will be effected when the long radius of the driver turns the short radius of the gear which carries the crank-pin.

The shaper shown in Fig. 257 has the tool-slide driven by a pinion which meshes into a rack upon its under side. The pinion is driven from either of two belt-wheels driven by open and crossed belts, to either of which it may be clutched by a double-friction cone, precisely as in the planer built by the same makers. This makes the tool the most direct inversion of the planer, and permits the length of stroke to be varied without stopping the machine. The position of the slide relative to the crank is made variable in the other forms by a long slot in the side of it. The pin for the free end of the connecting-rod may be clamped to any part of the slot.

The shaper appears in two forms, the pillar-shaper (Figs. 258 and 259), and the traveling-head shaper (Fig. 260). The pillar-shaper has the power-feed to the work given horizontally only. Vertical or angular feed is given by hand. The whole front has a vertical adjustment by screw and hand-wheel. In another form (Fig. 261), the slide is arranged vertically to secure stiffness from depth in the overhang. The table in this tool is made with a vertical face, to which work may also be bolted. The fly-wheel is preferred by some builders, in order to equalize the active and inactive strokes.

The older form of horizontal shaper belongs to the pillar class.

The shaper with traveling head is built for the larger services. The cone-pulley shaft is splined, and the head which carries the tool-slide carries also the driving-gear and crank. The whole head is fed by a screw along ways

on the top of the frame (Fig. 260). The feed is by a pawl and levers, and it is so arranged that the feed shall always be given at the beginning of a cut, and not at the end or in the middle. There are two tables, to which an object may be clamped vertically or horizontally, or to which any vise or centers may be applied. There is also a mandrel

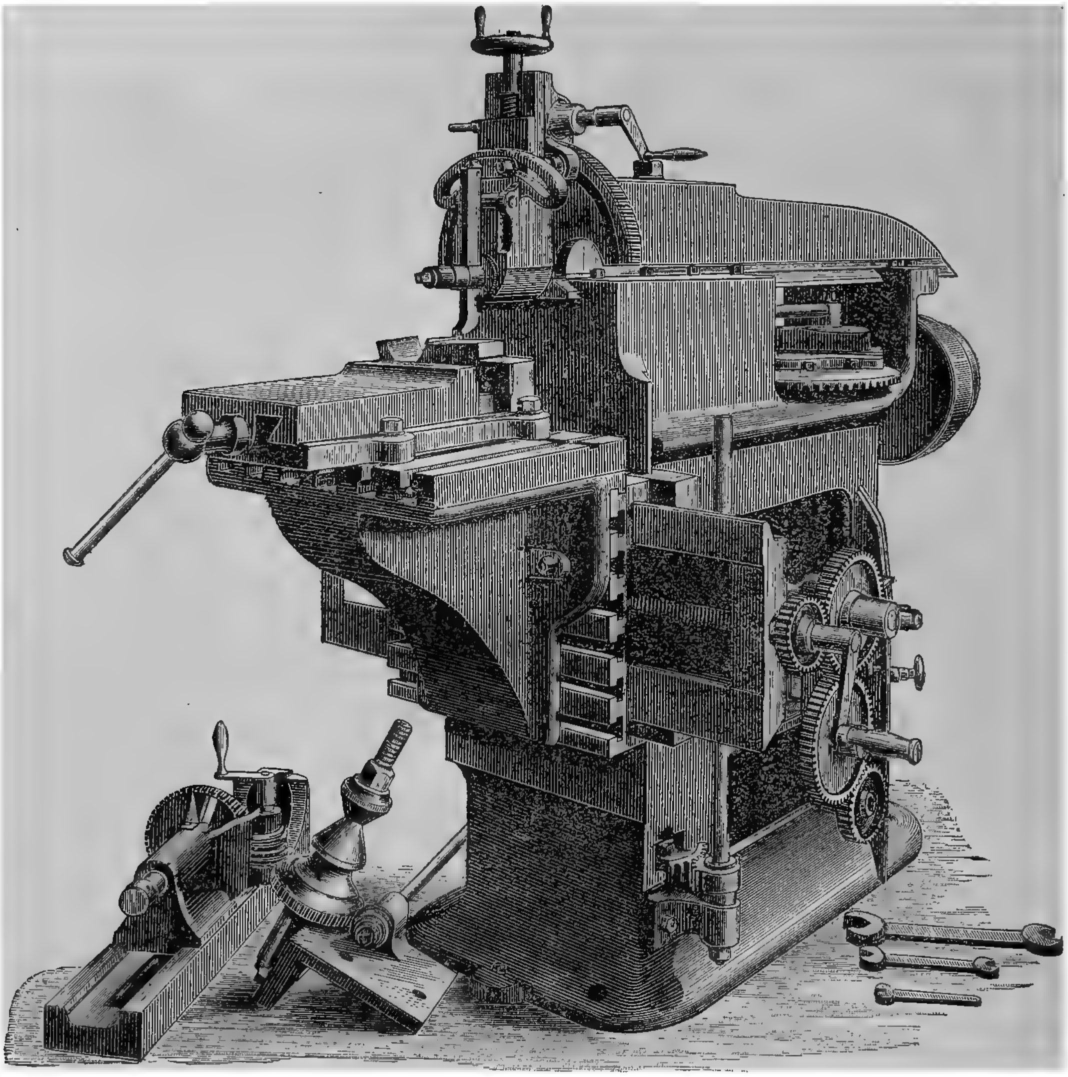


Fig. 259.

with cones for cylindrical work. The tables have a vertical feed-motion, and the tool may be fed vertically or at an angle, or may have a circular feed for concave or convex surfaces. The tool-feeds are given by hand.

Fig. 262 illustrates a similar tool, where the circular, vertical, or angular feed may be effected automatically. The stops give motion to the rod which is connected to a ratchet on the feed-screw by universal joints. The saddle, or head in this tool has quick hand-wheel traverse by the rack on the inside of its track. One of the tables is arranged to have a swivel top, interchangeable with the vise and centers. Fig. 263 shows a tool with similar capacities. Sometimes shapers are made with two heads upon one bed-plate to operate on both ends at once of long work, such as engine-rods and the like. These are called double-shaping machines.

Shaping-machines are especially applicable for small work, or for the finishing of small areas on large work. They are also adapted for finishing the curved surfaces of cranks or of levers with bosses upon them. They will also work rapidly on polygonal work, held in the centers. They do a variety of work which the planer could only do with less economy of time, and with less ease of management, beside requiring more power.

The fundamental principle of the shaper is often resorted to for work which is relatively very large as compared with the tools which are to operate on it. The work is bolted fast to the floor-plate or a bed-plate, and a tool is made to slide in front of the work and receives the proper feeds by hand. The tool may be held on a planer-bed which reciprocates at the side of a heavy casting.

A tool specially adapted for this class of work consists of two parallel rails which form the bed. Between them is a pit, in which may be laid the large work. The insides of the rails are fitted with inclined lugs and brackets, so that the work may be held and adjusted parallel to the shears on top of the rails. On the upper side of these

C.—TOOLS ACTING BY PARING.

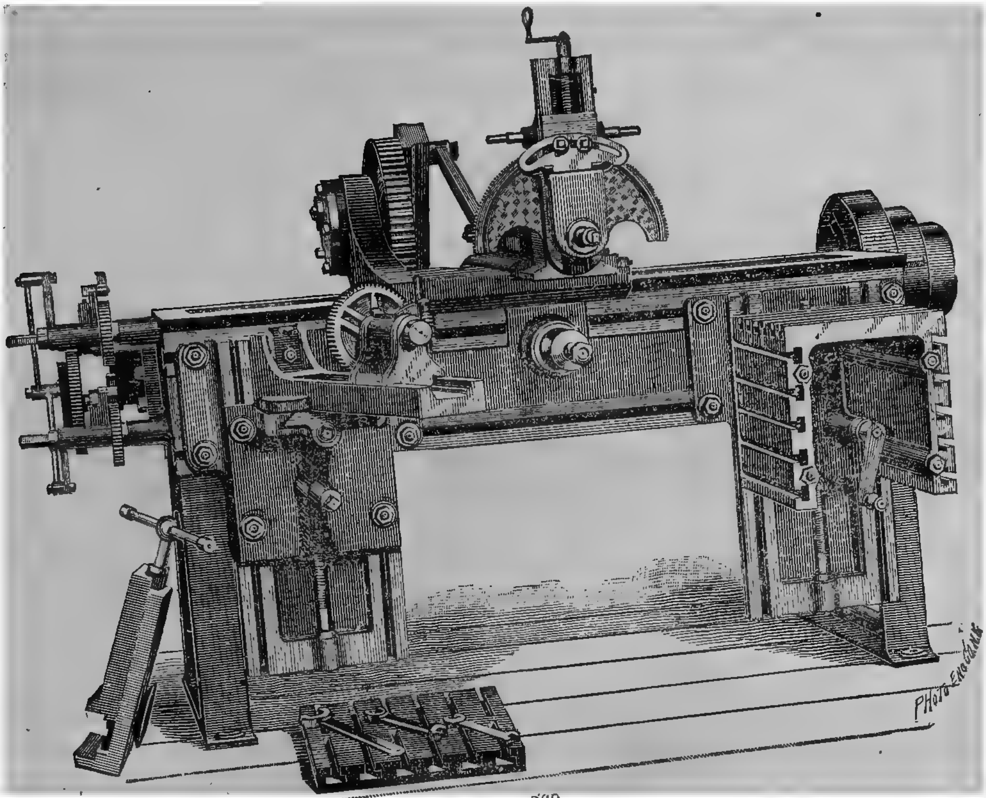


Fig. 260.

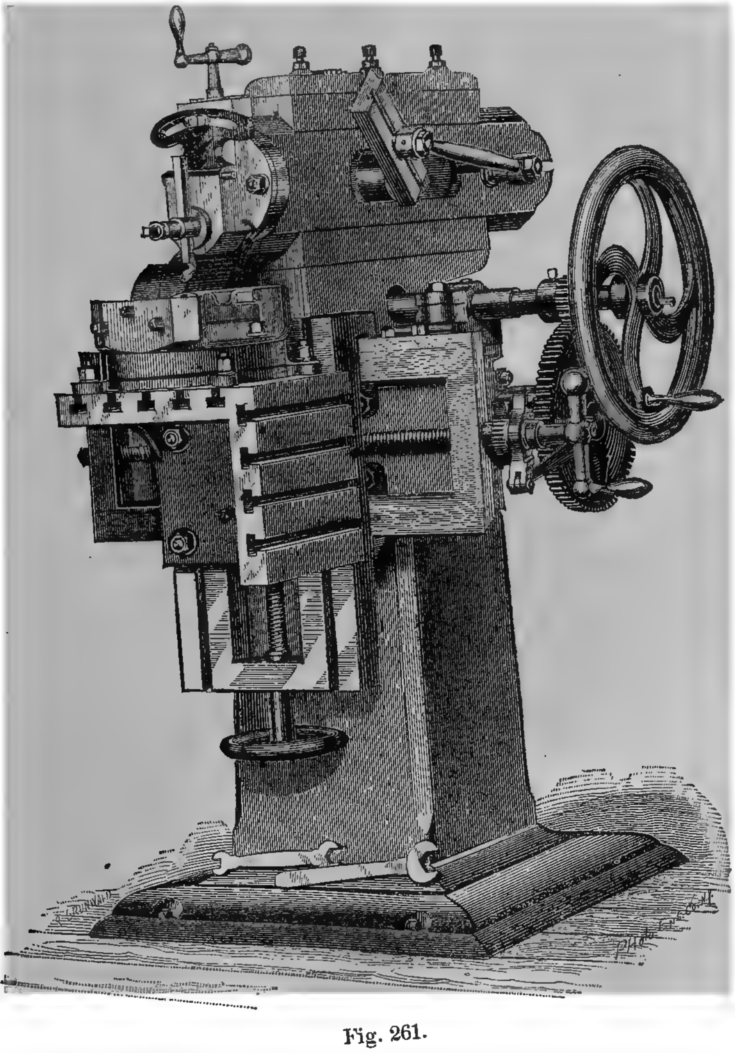


Fig. 261.

rails slides a stiff cross-rail spanning the pit and carrying shears and a saddle for holding tools. The cross-rail receives longitudinal motion along the rails by two screws between the shears of the primary rails driven by bevel-

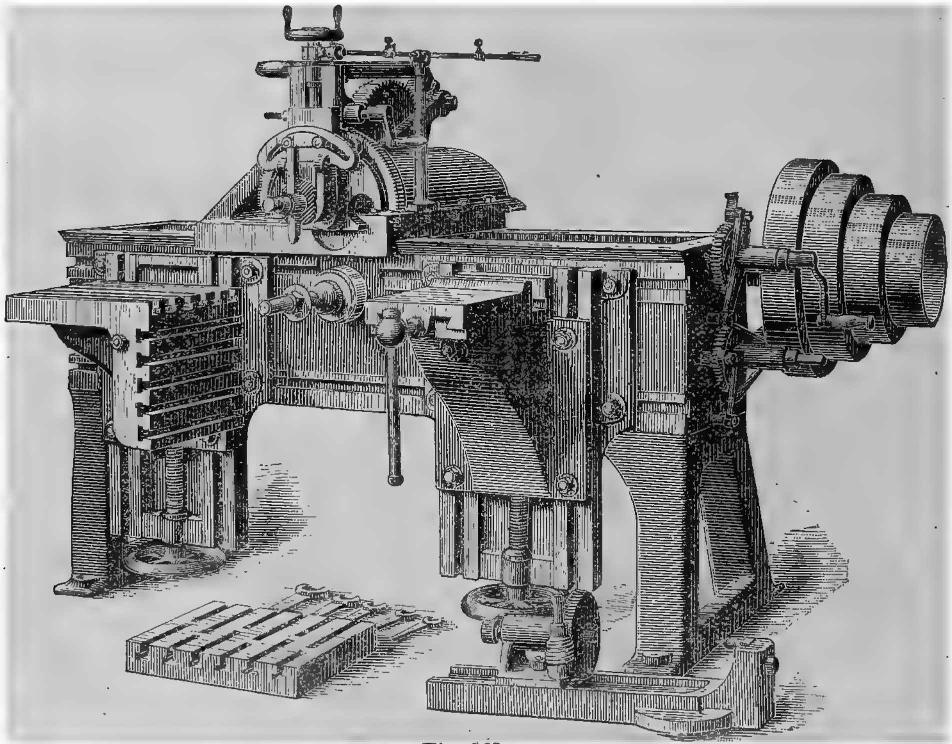


Fig. 262.

gear from the driving-shaft at the head. A very ingenious and simple form of holder keeps the horizontal screws from sagging, as the cross-rail nuts recede from the center, and so prevents jumping at the cut. This tool is particularly adapted for work upon heavy engine bed-plates.

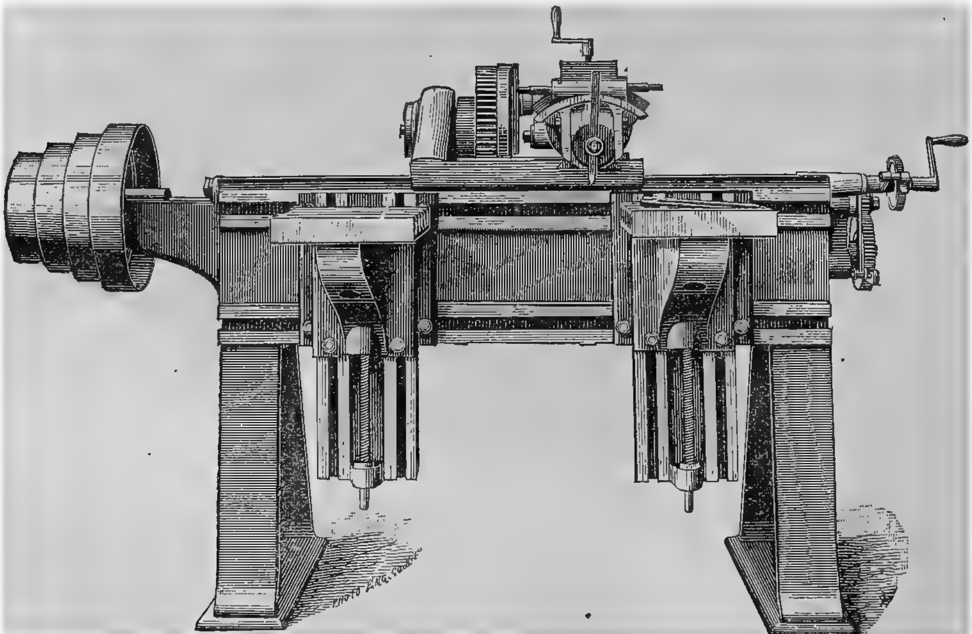


Fig. 263.

§ 29.

SLOTTERS.

The term slotting-machine is applied to a shaper with a vertical cutting-stroke. They are so often applied to the cutting of key-ways and similar vertical slots that their name has come from that one function.

The tool-slide is guided by the dovetail slides in front of the machine. In two designs these guides are adjustable, and may be brought down nearer the table to prevent any spring from the long overhang (Figs. 264 and 265). The reciprocation is derived from a slotted crank or wrist-plate, to which a quick-return motion is imparted by elliptical gear (Fig. 269) or by the Whitworth device. The slide-pin is adjustable in a slot, in which it may be clamped by a nut, or it may be carried upon a screw (Fig. 266). The tool illustrated has a convenient method for turning the adjusting-screw. The strain on the tool is in the direction of its length, consequently it needs to be clamped very firmly against the slide. This is accomplished in the smaller tools by means of two heavy set-screws. Not infrequently the cutting-edge is a simple "bit," carried in a large holder, which gives ample hold for the tool-screws. To avoid the dragging of the tool-point on the up-stroke, which its spring under the strain of the cut is certain to cause, the bit may be hinged in its slot in the holder, and fall away from the work when lifted. A

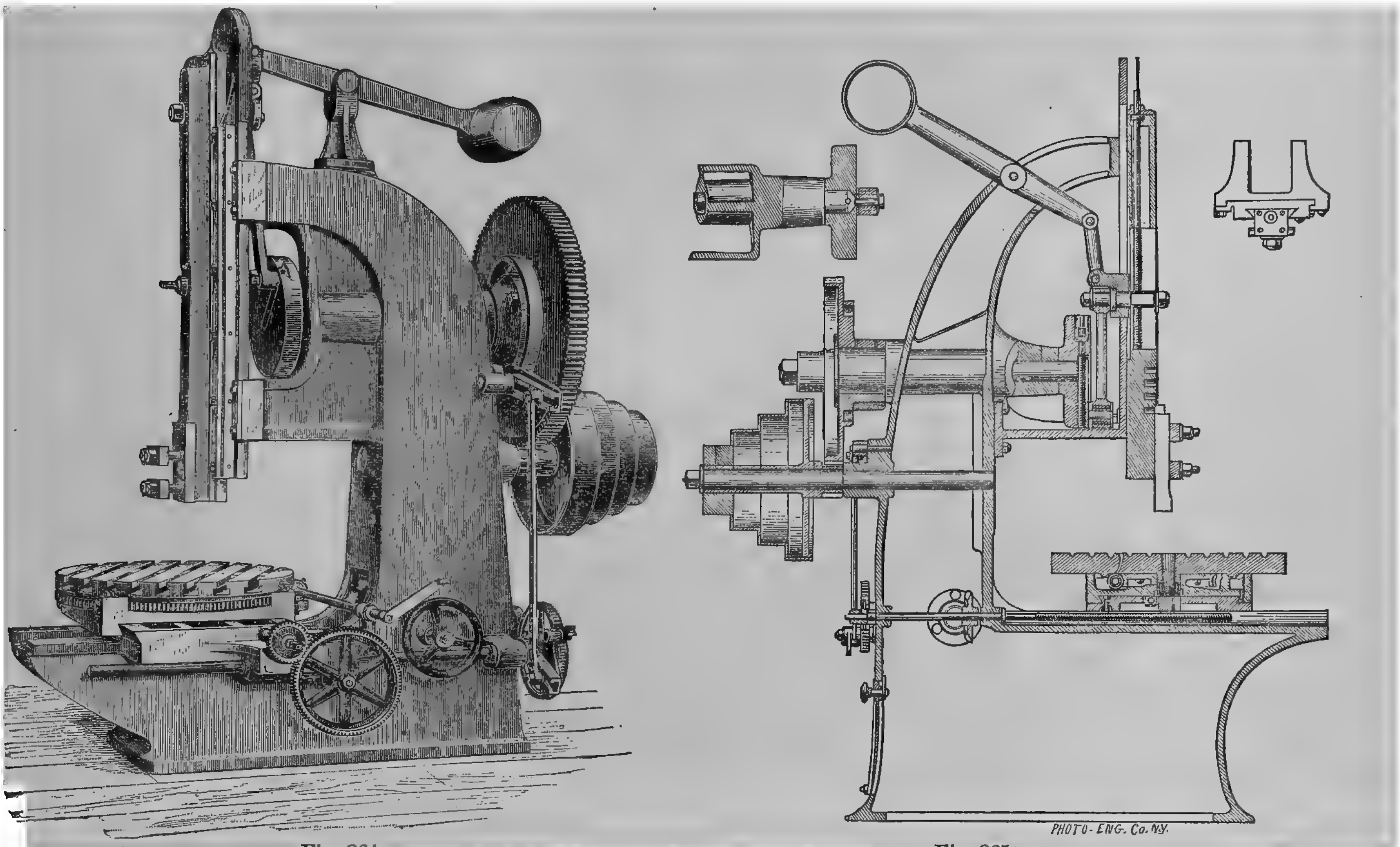


Fig. 264. Fig. 265.

spring forces the bit against the shoulder when it is released from its work (Fig. 267). For larger work an apron may be bolted to the end of the slide, acting similarly with the larger tool (Fig. 268). In the tool shown in Fig. 269 an especial device for the relief of the tool is one of the features. On the inoperative stroke of the feed-levers a motion is given to a screw of steep pitch which backs off the work from the tool-point. When the tool is up, this steep motion is restored and the feed is given in addition by the reverse motion of the levers. In this tool, and in that shown by Fig. 264, the adjustment for the slide-pin is made by the hand-crank on the squared arbor in front. A pair of bevel-wheels turns the screw on which the pin is borne. The quick return is effected by elliptical gear.

The slotter tables have three motions. They move forward and backward, to the right and left, and in addition will turn around a center by a tangent-screw combination. To prevent undesired rotation the circular top of the table may be clamped to the upper traversing slide by grooves in its periphery. The feed is given by a slotted lever, worked by a grooved cam on the crank-shaft. This gives motion to a dog-lever, which may turn slip-gears loose or with splines on the various arbors, which work the tables by screws. The tool-slide is counterpoised by a weighted lever connected to it by a link.

Some of the larger slotting-machines are driven by a rack upon one side of the slide. This rack is either with straight teeth, or the teeth may be made of the V-shape for smoothness. The designs of this latter class have the pinion for the rack driven by a worm on the belt-wheel shaft. There are pulleys of different diameters on it for the quick return, with open and crossed belts shifted separately. The stroke is controlled by dogs in a slot of the slide. Some of the older and larger slotters attain the quick return from one belt. This is shifted from a pulley fast to a shaft which carries a small bevel-wheel, to a pulley on a sleeve turning on the first shaft, which carries

an equal bevel-wheel, facing the other way. These bevel-wheels turn others of different diameters on the first shaft of the pinion-train, and thus operate to reverse and to cause the quick return, when the belt is shifted by the motion of the tool-slide.

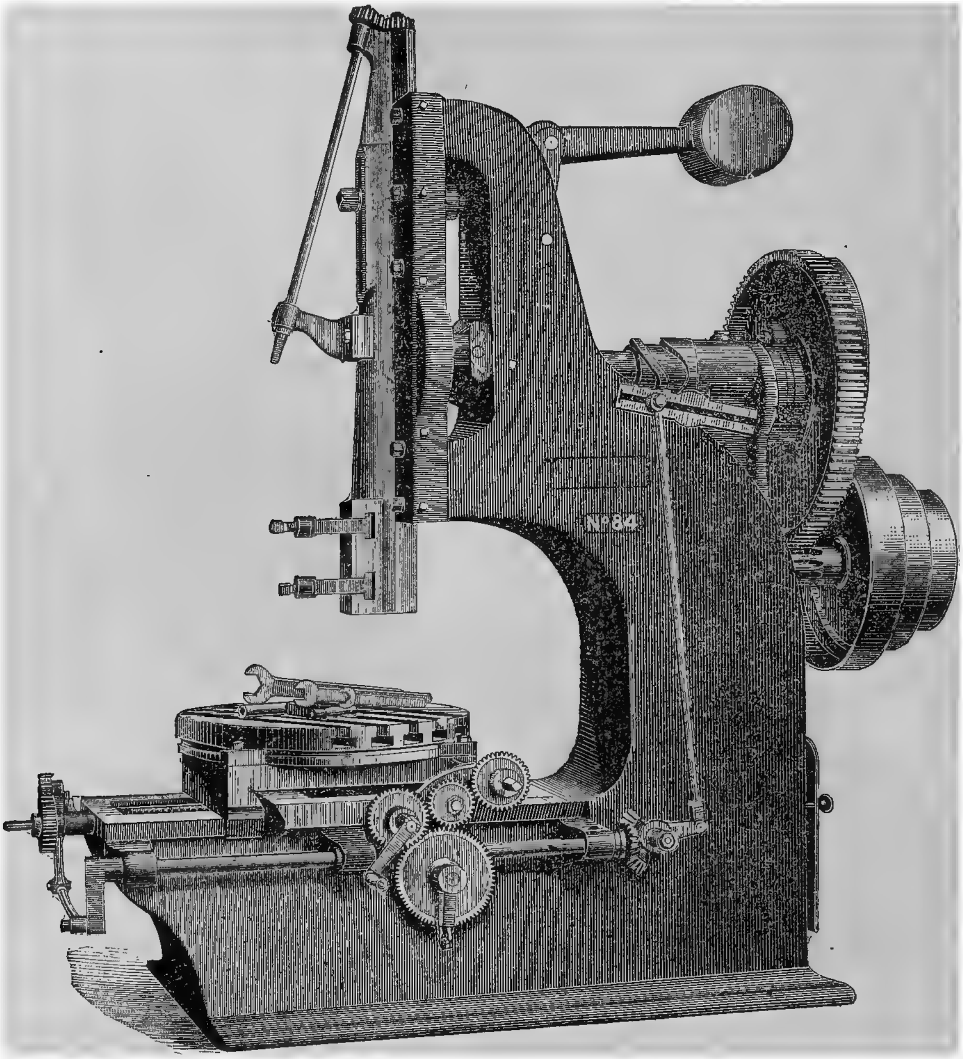


Fig. 266.

For the very largest slotters, a screw of steep pitch moves the tool-slide. On a tool of this class for the heaviest work, the piece is chucked to a heavy floor-plate, and the upright which carries and guides the holder

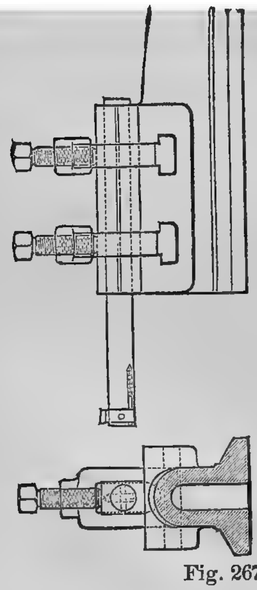


Fig. 267.

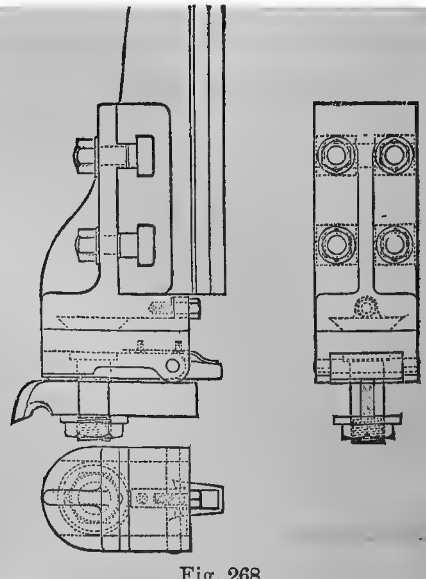


Fig. 268.

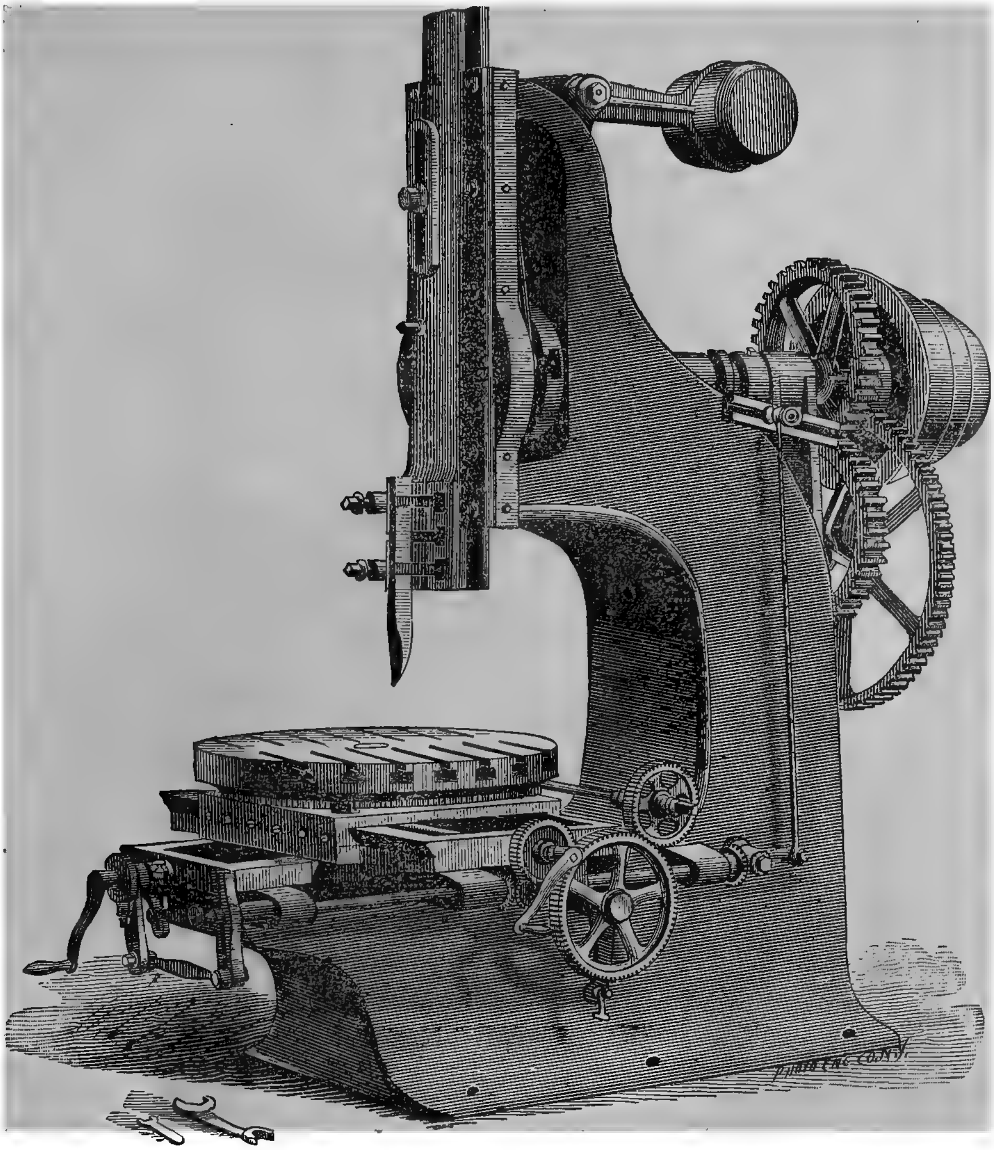


Fig. 269.

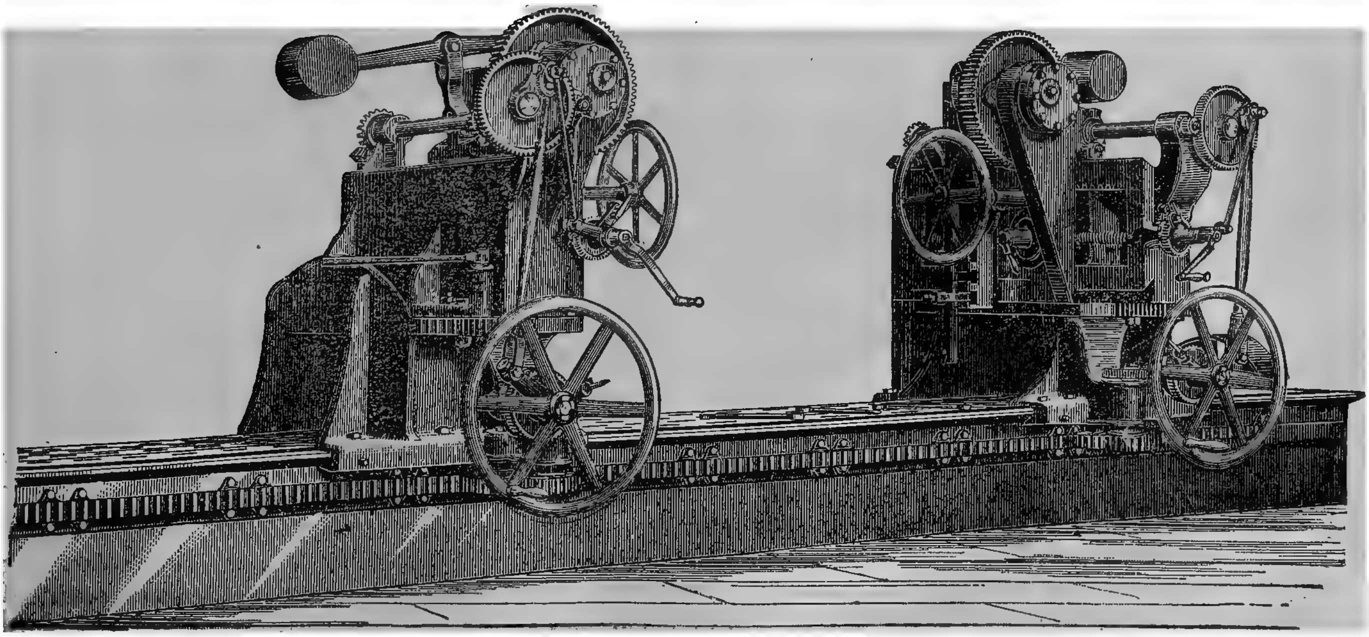


Fig. 270.

slides in front of it as fed by a screw. The quick return is given by two belts to a geared splined shaft in the bed below the upright which drives the cutting-screw. The shifting is effected by dogs on a horizontal slotted disk, and the feed is controlled by shields which may admit any desired engagement of ratchet-dogs in either direction. Some heavy slotters, self-contained, have been built with two heavy pillars bolted to the bed-plate which carries the compound table. These pillars are at the two ends of the bed, and support a heavy entablature upon which the train of driving-gear is carried. When these tools are used for heavy profiling, the cutter is pivoted in the holder between cheeks. The long tail of the cutter acts as the spring of the smaller holder previously shown, to permit release on the up-stroke, and to bring the cutter to the shoulder of the holder for the cut.

Fig. 270 illustrates a special form of slotter for dressing the welded frames of locomotive-engines. The two heads face each other, and are driven and operated separately from the splined shafts at the rear. The slide is borne upon the cross-rail, and has automatic feed across the table, while the entire head may receive longitudinal

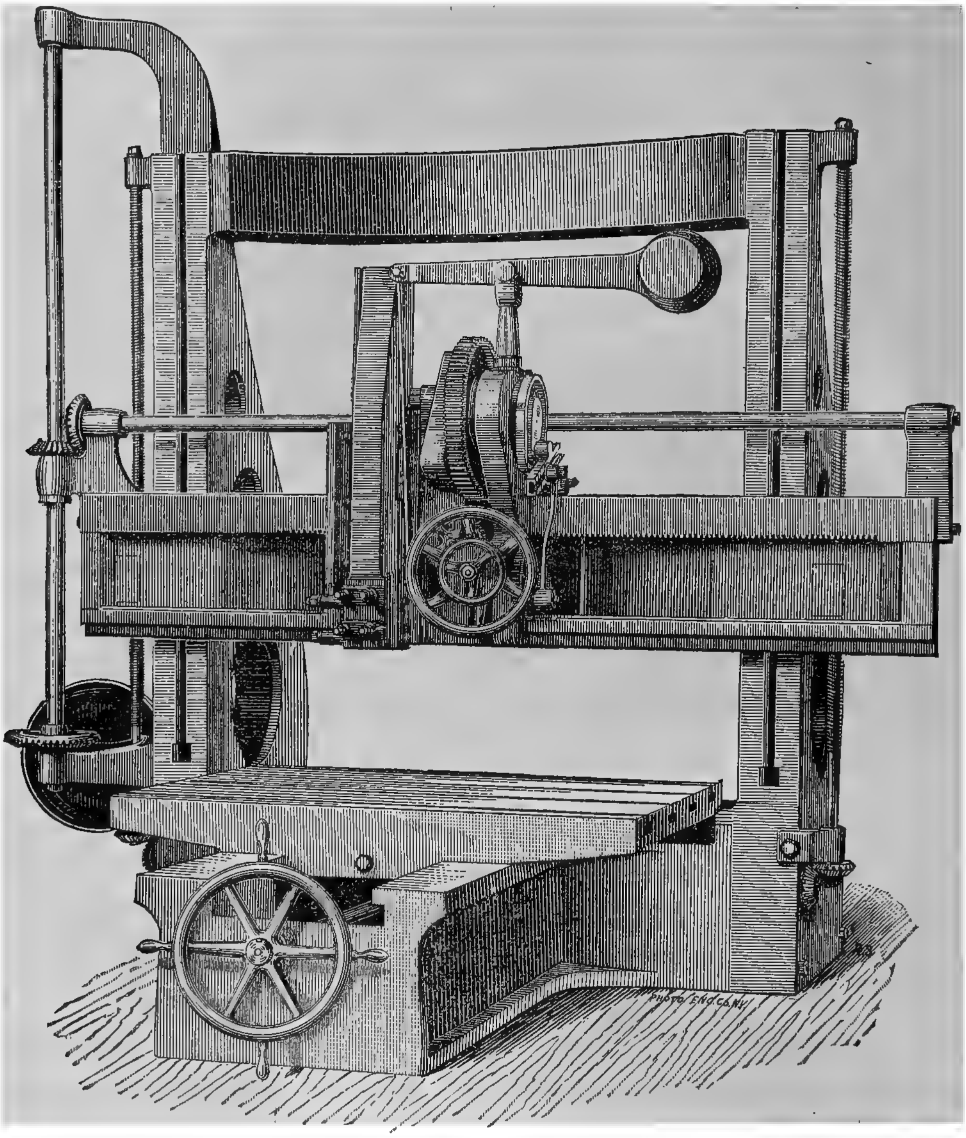


Fig. 271.

feed. The feed-cam is made adjustable upon the gear-wheel which turns the slide-crank to bring the feed in any desired relation to the end of the stroke. For slotting the jaws for the boxes of the driving-wheel axles the heads have an angular adjustment by a pinion and sector, so as to cut obliquely to the line at 90° with the axis of the bed. The saddle has a rapid motion by hand-wheel and rack.

Fig. 271 shows another form of plain traveling-head slotter. The slotting-machine is especially adapted for profiling of heavy work, especially where the profile is much broken. The work may be secured to the table with ease, since gravity assists in holding it there. The table also opposes a direct resistance to the cut, so that the strain of holding the work does not come upon the chucking devices with increasing leverage as the dressing progresses. Large cranks and similar work could be as easily dressed into shape upon no other tool, and for cutting off and cutting up scrap for reforging it serves an admirable purpose.

Fig. 272 shows a tool upon the dividing line between the slotters and the milling-machines. It is for cutting key-seats and similar work. The cutter reciprocates with a quick-return motion from the crank and slotted lever.

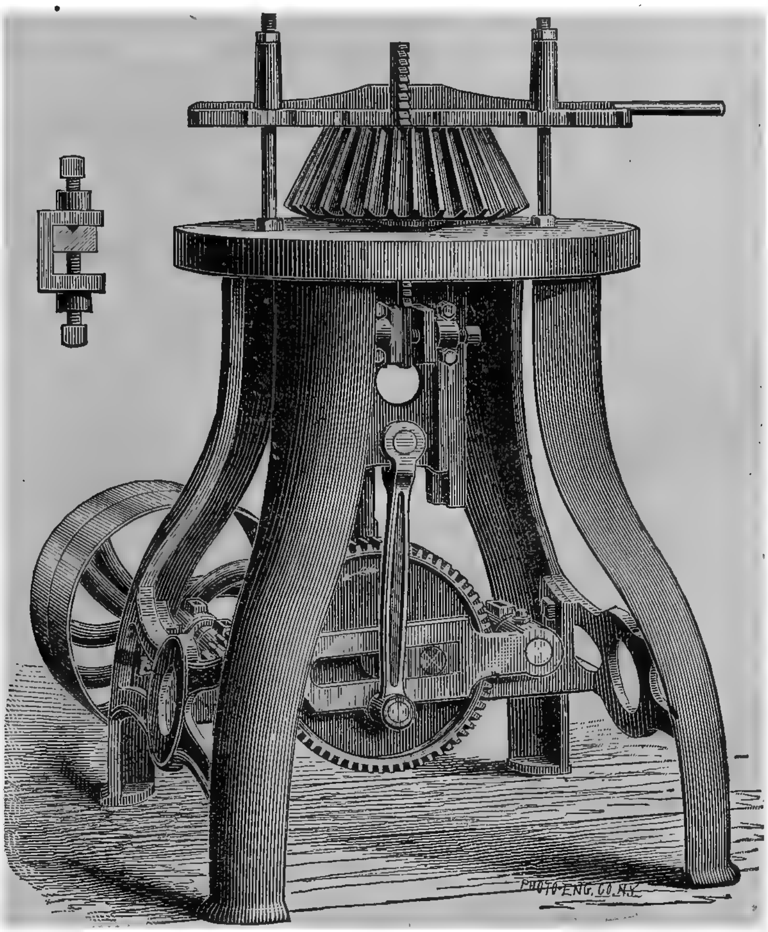


Fig. 272.

The cutting is done by the teeth on the point of a bar which resembles a developed milling-cutter. It can, of course, pass through a hole of quite small diameter.

§ 30.

D.—MILLING-MACHINES.

The term milling-machine may be applied generally to all metal-working tools operating with serrated rotary cutters. Where the cutter is very thin, the machine becomes a metal saw; where especially adapted for one operation, it is often known by a special name; but it still retains enough fundamental features to justify its classification with the typical machine.

The use of the milling-machine is attended with certain conspicuous advantages. These are the result of the revolving cutter, and the resulting elimination of spring in the tool. A great saving of time results from the continuous action of the cutters. There is no return or inactive stroke as in the reciprocating tools. The cutting-edges are very near to their points of support. Therefore exactness of dimensions may be insured and uniformity in duplication of irregular shapes. Again, the cutting-edges of the rotary cutter compel an outline of the work whose form accords with that of the cutter. Hence, if a pattern of cutter be fixed upon by a skilled mechanic, the reproduction of duplicate forms can be intrusted to a less skilled operative. Provided only the cutters are maintained in shape, and the work is properly chucked, the machine can be worked to stop-gauges without the repeated application of standards. For these reasons, the milling-machine in its various forms has become an essential in the manufacture of exact machinery. Operators become easily accustomed to working to a thousandth of an inch, and for fire-arm, electric, and sewing-machine work they have revolutionized the practice of earlier days.

One of the earliest forms of milling-machine for gun-work is illustrated by Figs. 273 and 274. In both the machines shown great improvements have been made over the original machine as made many years ago. The driving-spindle rises and falls in the uprights, controlled either by two screws geared (Fig. 273) or by one screw, equalized between the two boxes by a cross-head and stiff plungers (Fig. 274). Lost motion is prevented by the

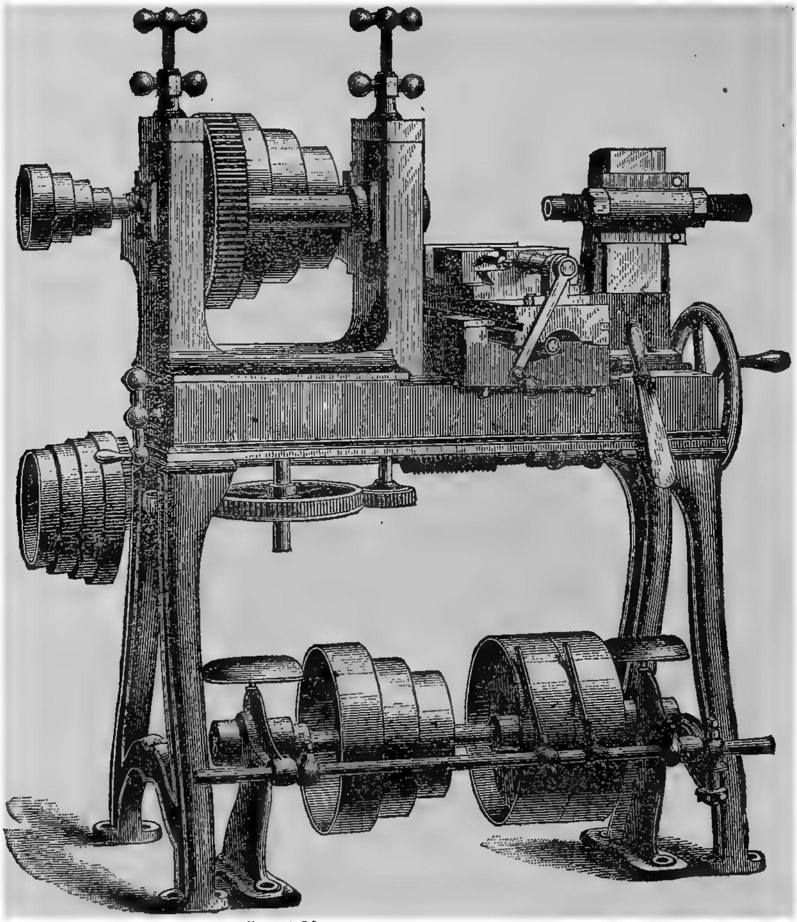


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Fig. 273.

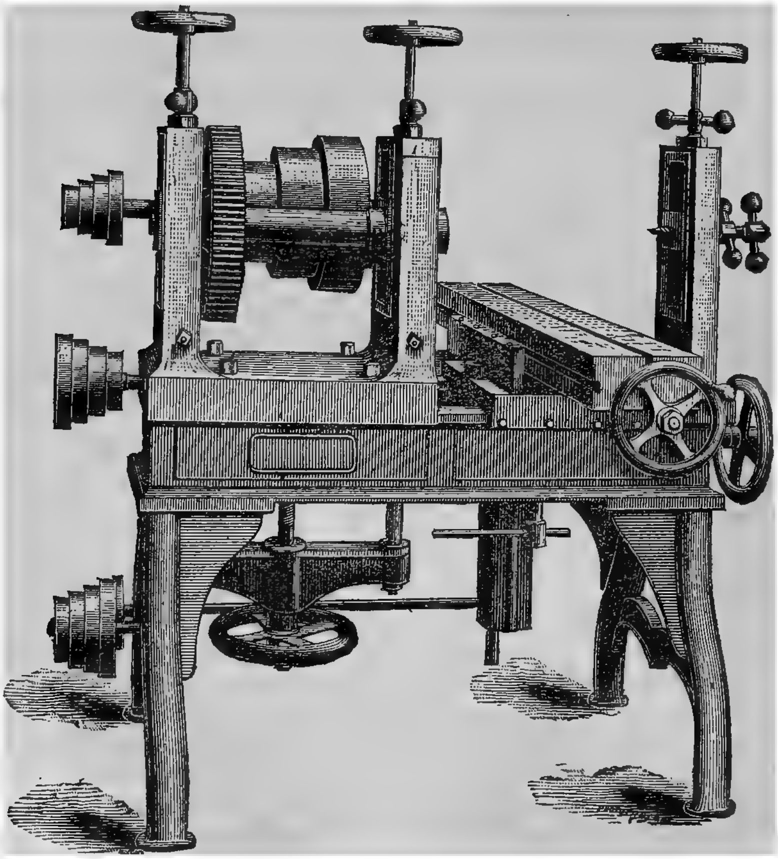


Fig. 274.

jam-nuts on the top screws. The cutters are held on a mandrel, which fits into the end of the spindle, the outer end being borne by an adjustable center. This has a motion independent of that of the spindle, for convenience of taper work. The spindle is geared to a pulley-shaft, the latter shaft being adjustable laterally for various elevations of the spindle. There will be three or four grades on the cone-pulley. The piece to be operated upon is clamped in a vise or chucked to a table, which may have two motions. The motion along the axis of the cutter-mandrel is quite short, and is usually by hand only, for adjustment. The motion at right angles to this line and against the cutters is much longer and is automatic. A worm-shaft is driven by small cone-pulleys, and turns a worm-wheel,

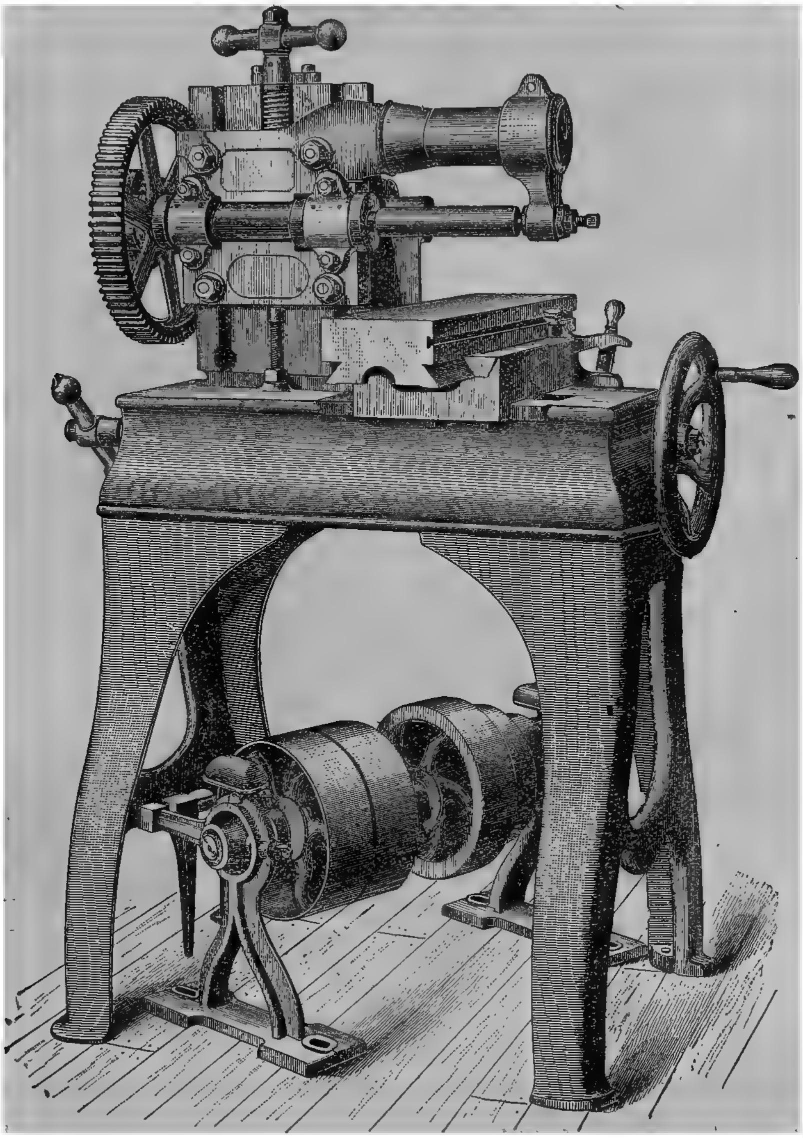


Fig. 275.

which meshes into a gear on the cross-feed screw. The worm-shaft is carried on a swivel-bearing at the head-stock, and the further bearing is connected to a pivoted lever. When this lever is latched up the worm turns the wheel. The release of the latch, either by an automatic stop or by hand, permits the worm to drop out of gear with the wheel, and stops the feed. The worm is made long so as to operate wherever the table may be in its longitudinal traverse.

Fig. 275 shows the construction of a machine, which is in some respects an improvement on the earlier forms. The spindle is held on a flat plate sliding in slots to which it may be clamped by bolts. It is adjusted by one large screw, and has a stop-screw below. The pulley-spindle swings on a yoke and is linked to the main spindle, rendering the lateral adjustment of its bearings automatic. The heavy slide insures parallelism of the main spindle at all times, which the unequal wear of the gears and screws of the earlier form was liable to vitiate. The feed-motions of the table are as before. Instead of a back-carrier stand, adjustable for mandrels of different lengths, an outside center support is attachable on an arm from the carrier. These will all move together and can be adjusted while the machine is in motion. A similar design is shown by Fig. 276. Milling-machines of this type are known as

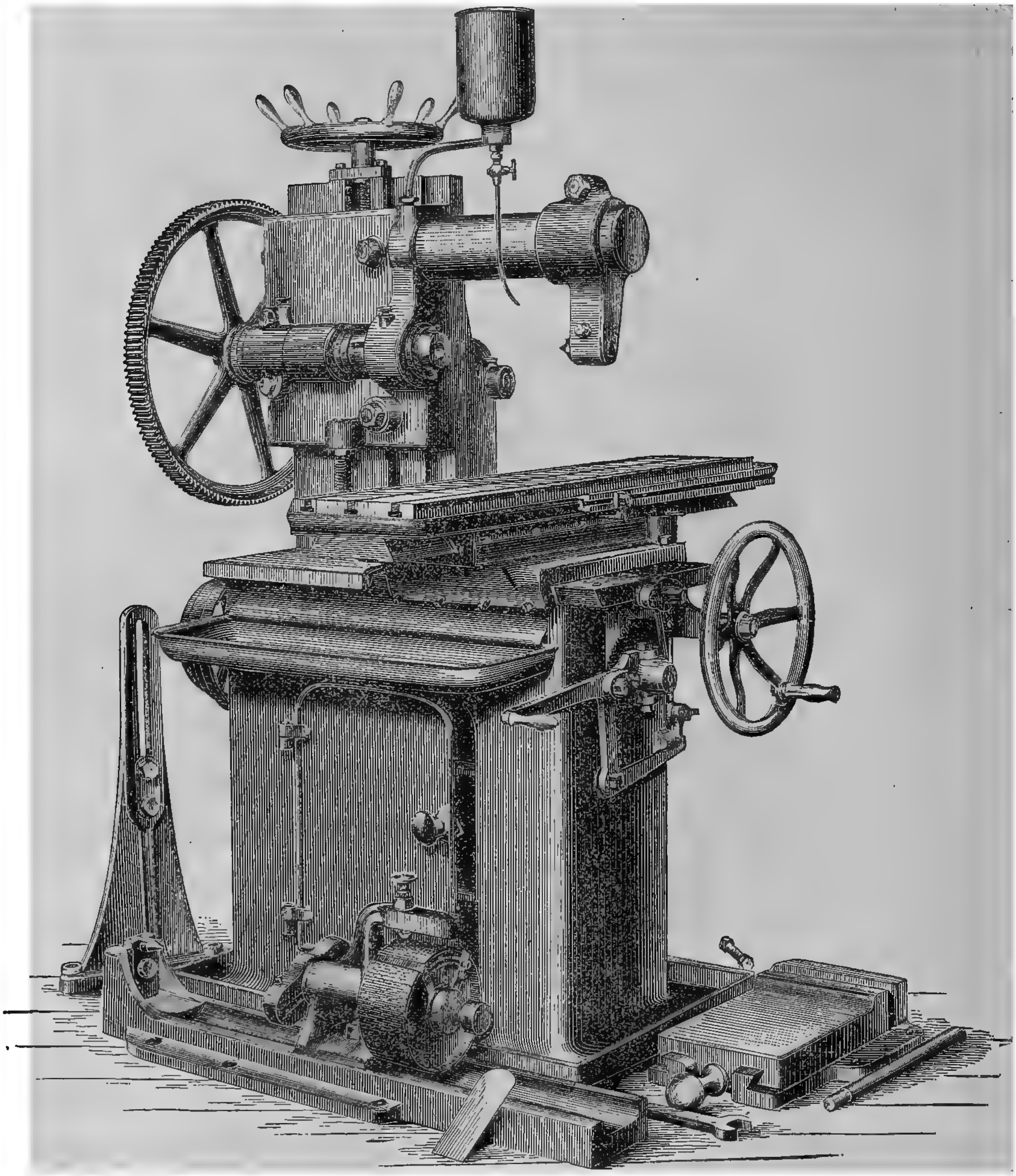


Fig. 276.

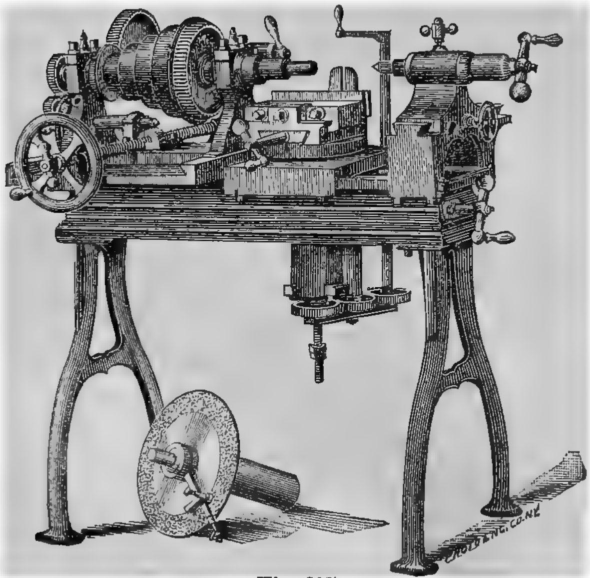


Fig. 277.

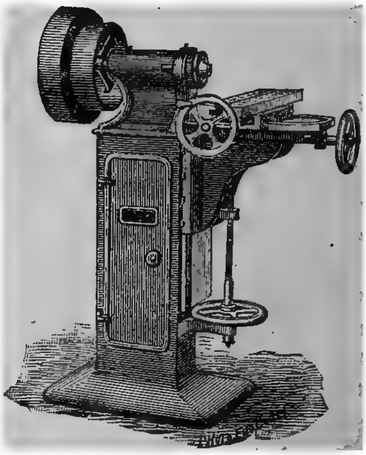


Fig. 278.

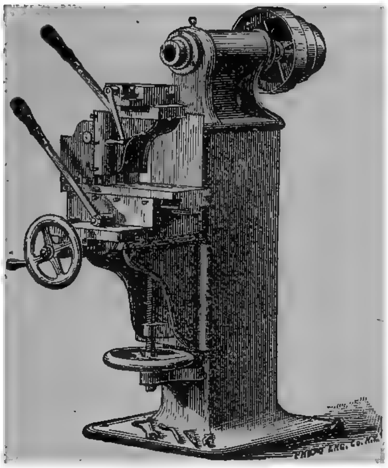


Fig. 279.

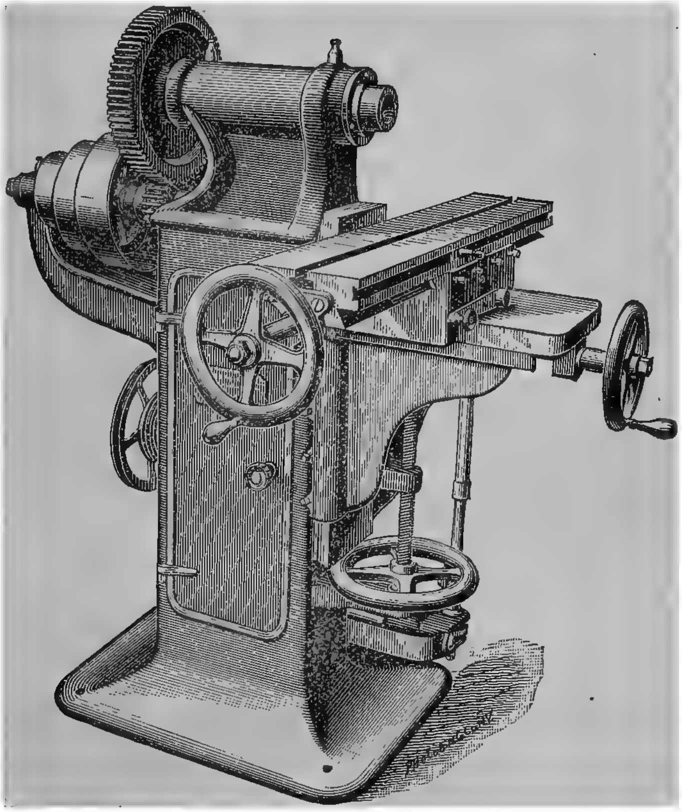


Fig. 280.

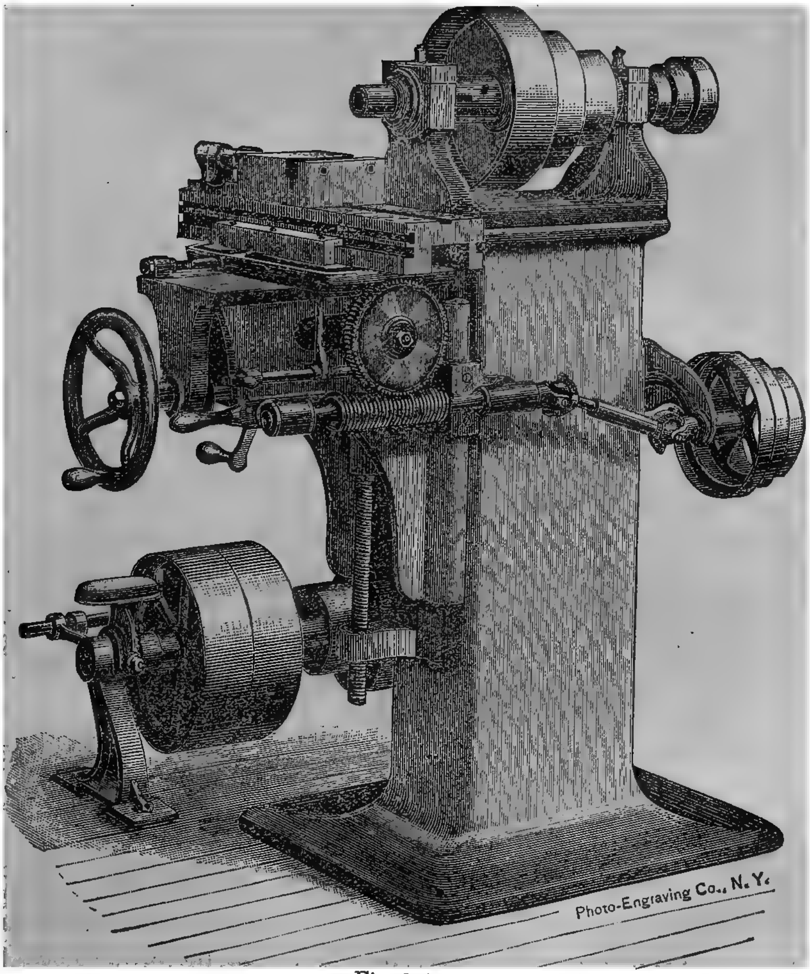


Fig. 281.

"plain" milling-machines. A milling-machine of a slightly different construction, but similar in principle, is shown by Fig. 277. The vise receives the vertical feed, and both the main and tail spindles have set-over motions. The tool illustrates the application of the lathe principle to milling purposes.

The second form of milling-machine is what is known as the "standard" machine. The working parts are borne upon a column or standard, which in many designs makes a convenient tool-closet for the attachments.

Figs. 278 and 279 illustrate types of the hand-machines. The spindle is driven directly by belt and the knee-table gives a vertical adjustment while the back-and-forth and right-and-left motions are given to the compound table. These are adapted for work with small cutters only, which turn at high speed, and the feeds are by screw or by rack and pinion by the levers.

Fig. 280 illustrates a larger design of standard miller with power-feed across the front. The screw on the hand-wheel shaft is turned by bevel-gear from the vertical telescopic shaft in front, which is driven from a worm-shaft at the base of the tool, as shown by Fig. 284.

Fig. 281 shows another way of producing the feed-motion by a long worm which may be disengaged by hand-lever in front. To compensate for rise and fall, the cone-pulleys are connected to the worm by two universal joints and a telescopic shaft. The double joint also prevents the irregularity of feed from being as noticeable as it would be with but one. There is an automatic stop-motion for the feed, adjustable to any position. There is also a stop by jam-nuts upon the in-and-out hand traverse.

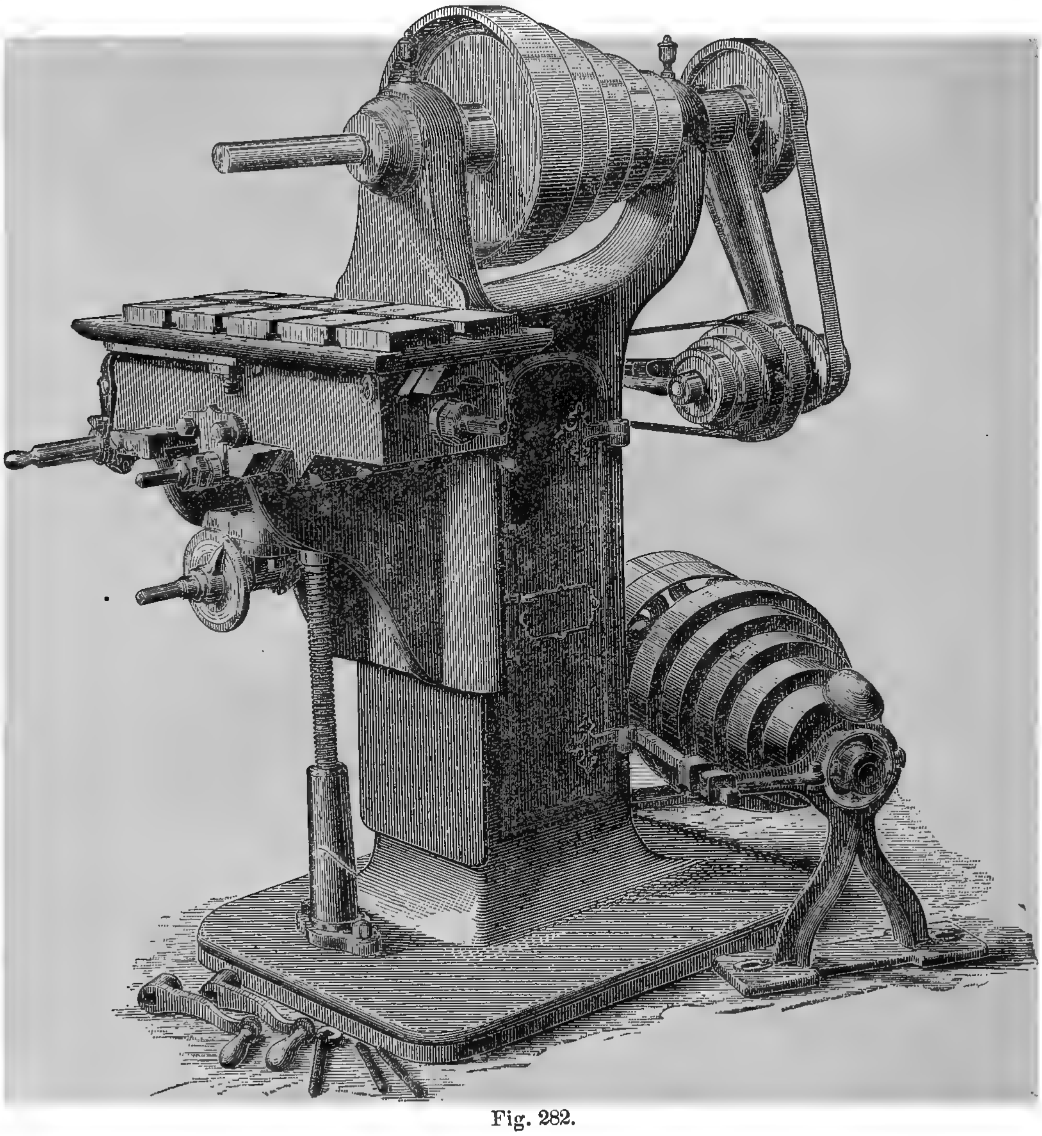


Fig. 282.

Fig. 282 shows the feed-worm driven by belts through a floating cone-pulley shaft. The stiff link swings around the box of the spindle, and an extensible link swings round the worm-shaft. The worm-shaft can thus be more accurately fitted to the adjustable table, and the tension of the driving-belt may be varied at will. The extensible link is forked and bears at both ends of the arbor. The spring latch at the left is acted upon by the adjustable stop under the oil-pan in front. The elevating-screw is turned by bevel-gear and is fitted with a graduated circle

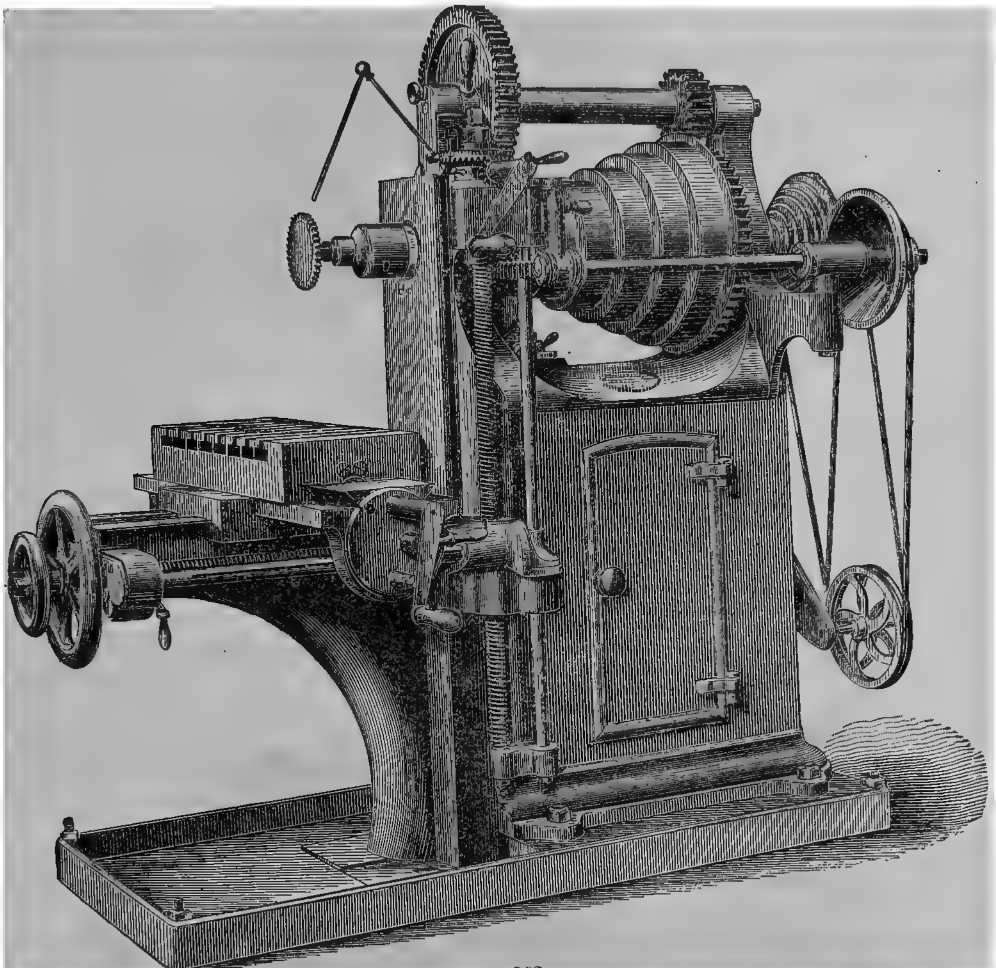


Fig. 283.

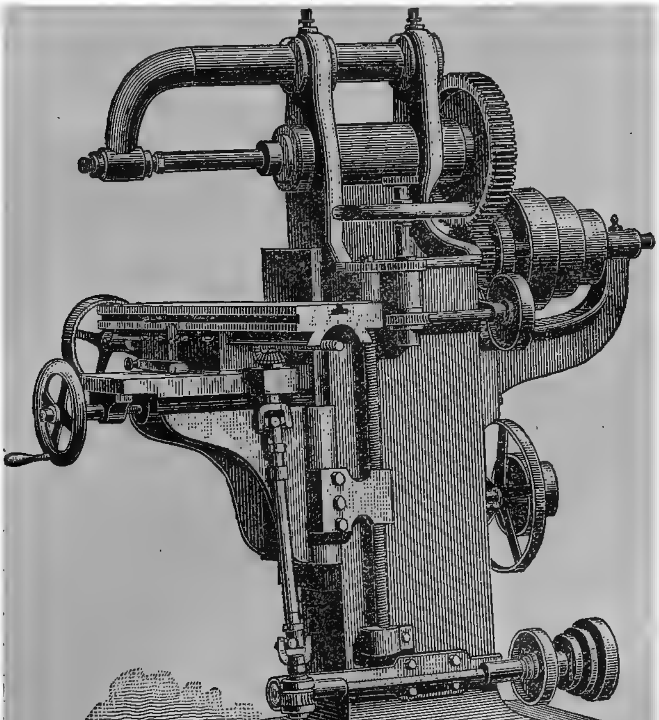


Fig. 284.

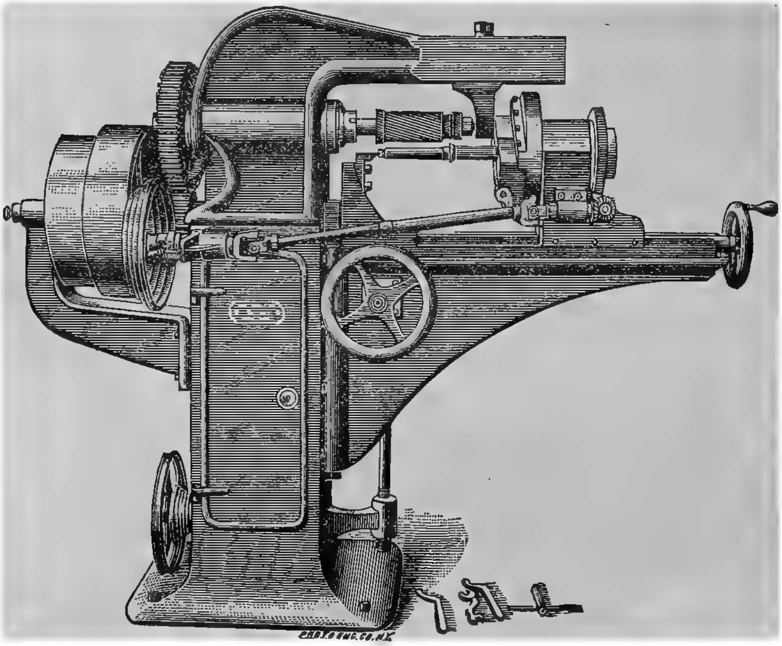


Fig. 285.

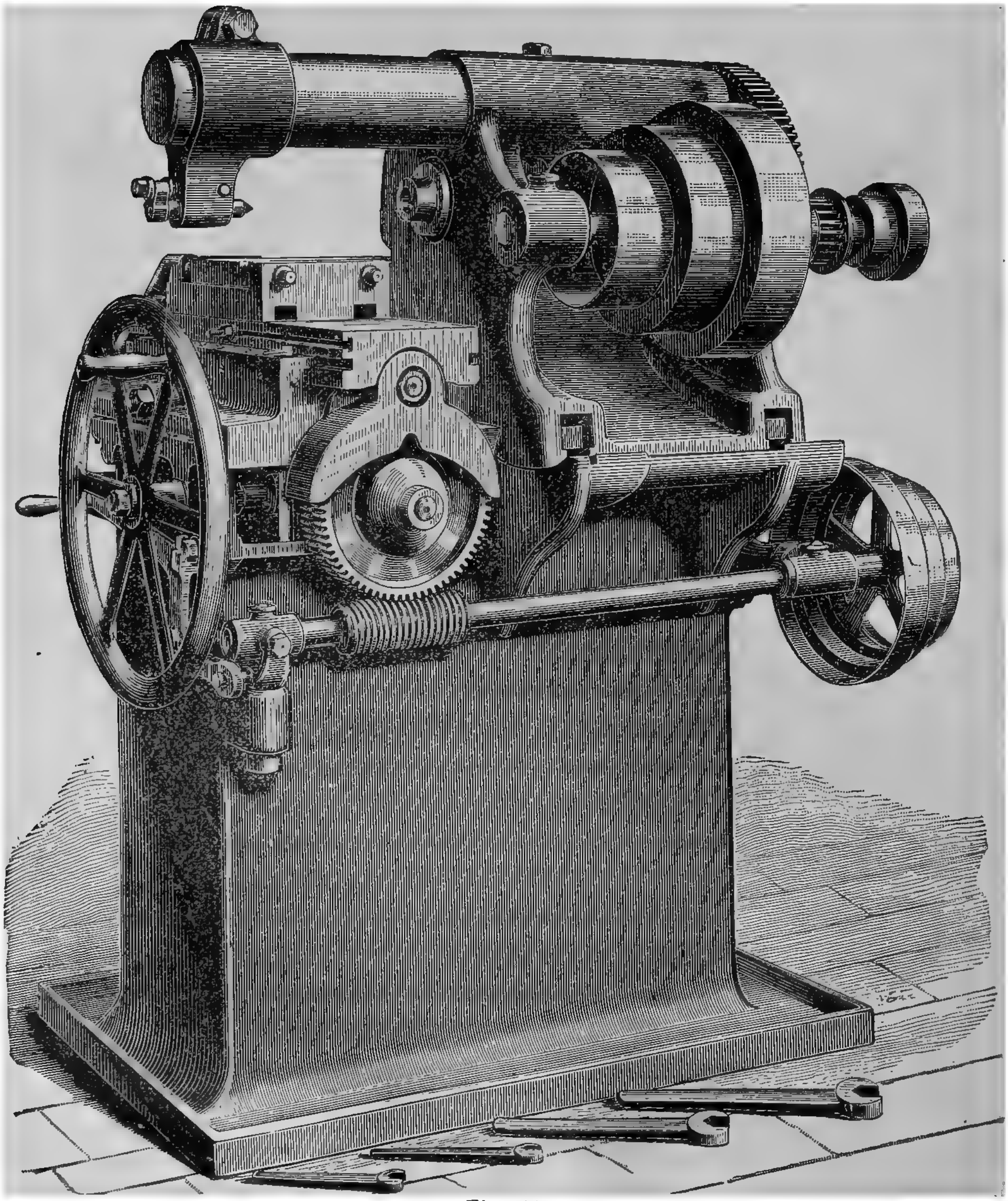


Fig. 286.

D.—MILLING-MACHINES.

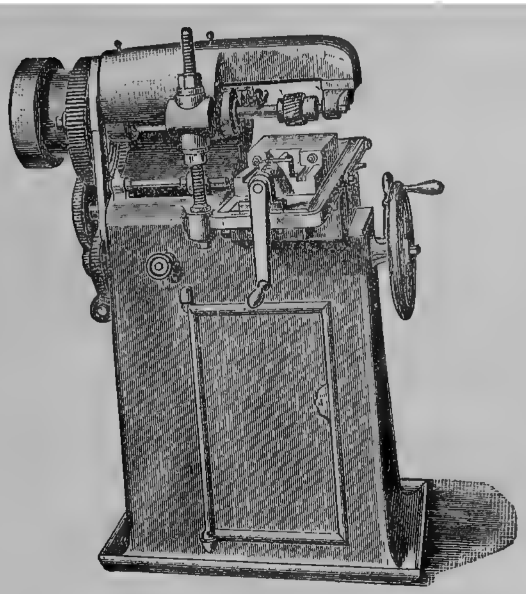


Fig. 287.

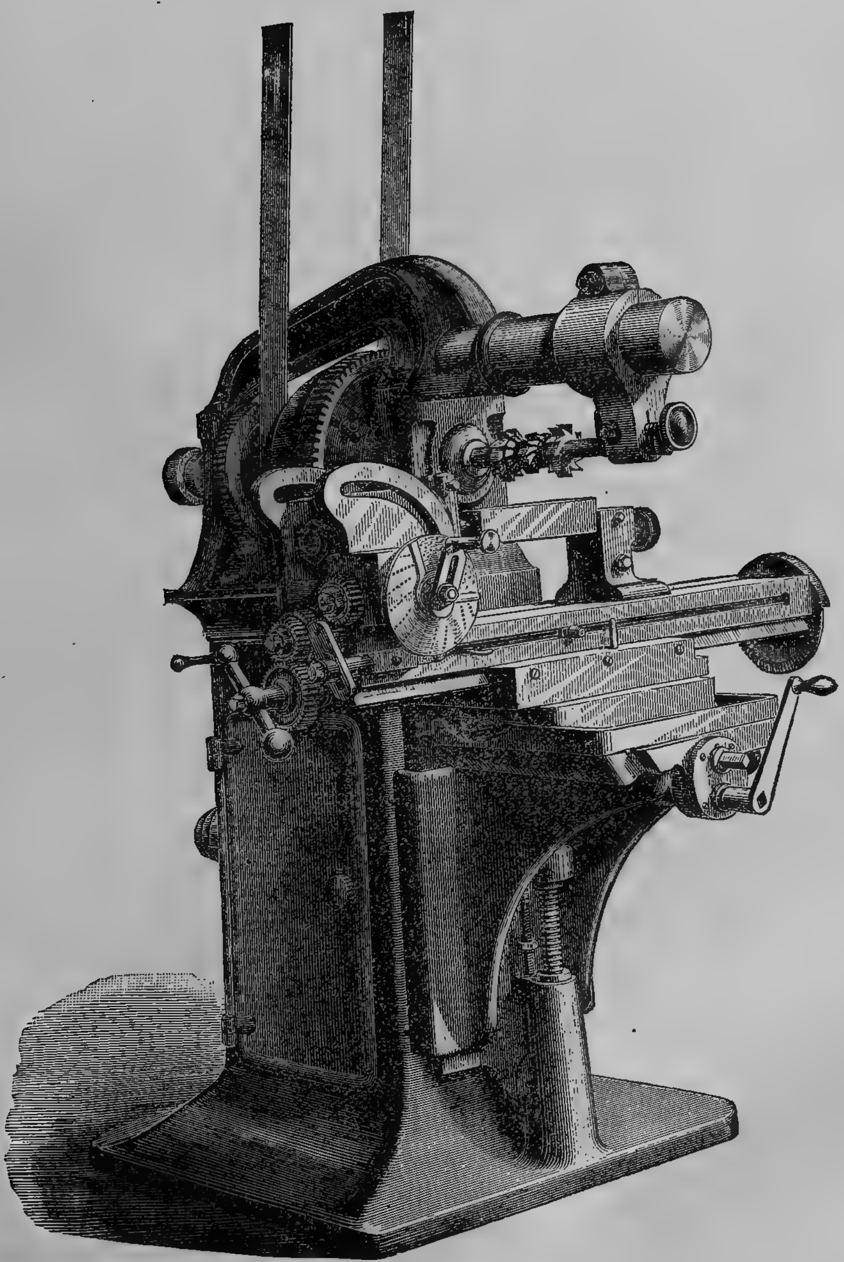


Fig. 288.

and index. By dividing the circle into 125 parts and using a screw of one-eighth of an inch pitch, the table may be raised by one-thousandth of an inch, or by one-half of that by ocular bisection of the graduations. The traverse in line with the spindle is by hand over 5 inches only.

Fig. 283 shows a type of back-geared milling-machine, with feed in all directions to the compound table. A twisted round belt transmits motion through a floating stud to a shaft with short worms, right and left. These may be engaged at will with a worm-wheel on a splined shaft which transmits motion by bevel-gears to a second splined shaft at the side of the knee-table. From this the motion is taken off by gears to the cross-feed screw at the end, and for the longitudinal feed. The feeds are disengaged by the short hand-levers shown near the screws. The knee-table is lifted by the screw at the side, the bearing being very long to resist twisting.

For larger tools it is necessary to have an outside center support for the mill-arbor. The strain of the cut might deflect the arbor and cause untruth in the work.

Fig. 284 illustrates an unusual way of accomplishing this result. The arm passes through rings and is set in place by screws, so as to uphold the mandrel by a center. The table has vertical and transverse hand- and power-feed by narrow belts to worm-shafts.

In Fig. 285 the arm for the center is cast with the head, and is not detachable, as is customary. The hanging arm bolts the center through a slot, by which arbors of different lengths may be accommodated. The cut illustrates a tool of this class applied for the special duty of milling out the profile of a carriage-axle at one operation. The square of the axle receives feed-motion by a tangent-screw to the special-holder vise. A type of solid arm, with adjustment vertically, is shown by Figs. 286 and 287. In both figures the compound table has no vertical adjustment for differing thicknesses. This gives steadiness to the table and for its motions, and simplifies the feed connections. In Fig. 286 the casting which carries the arm and spindle is fitted to a concave arc on the standard. The center of the two arcs is the center of the cone-pulley shaft. The movable casting slides on tenons in the arc of the standard, as governed by a screw at the rear, moving tangent to the arc. By this means a vertical adjustment of 6 inches is possible, without interfering with the driving-belt. In Fig. 287 the arm and spindle-casting is hinged at the right, and a pillar-screw and jam-nuts secure the swinging arm in the proper adjustment. The motion takes place around the center of the gear-axis as before.

The most familiar types of the universal standard milling-machine are shown by Figs. 288 and 290. They embody the highest refinements of construction for exactness and finish, many of which are applied in the smaller machines as well, or may be omitted or replaced in designs of less elaboration. In Fig. 289, which shows part of

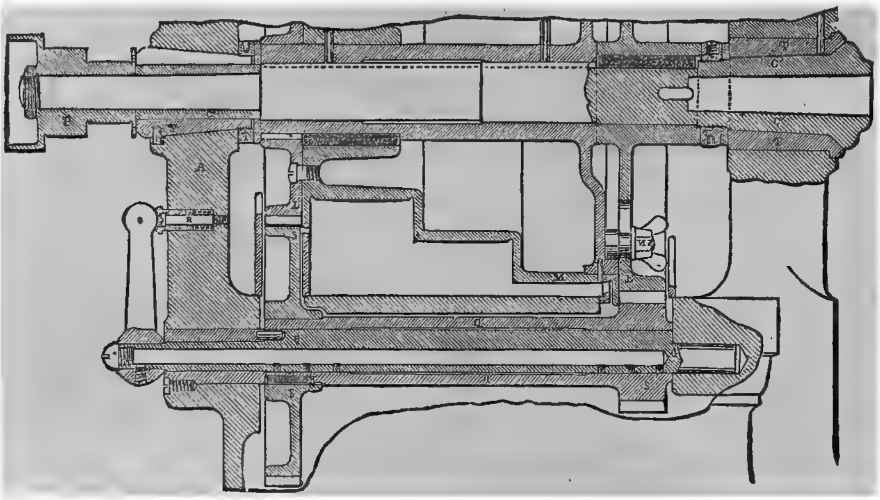


Fig. 289.

the detail of the head of the machine, the spindle C C′ is of hammered steel, hardened and turning in hardened boxes. The spindle is ground at front of box to tangents to the Schiele curve to receive the thrust on the end. A long taper socket is made in the spindle to receive the ends of mandrels. The front box is solid, forced into the supporting casting. A capstan-nut with set-screws on the spindle can take up any lost motion from wear, by drawing inward the conical bearing. The rear box is split, and wear is taken up by a capstan-nut which compresses the box upon the journal as it draws inward the cone of the outside of the box into the casting. Back-gearing is applied below the main spindle, a spring catch holding the engaging-arm in place. The outside center support is bolted to the top of the uprights of the spindle-bearings, and the center clasps the finished arm by a bolt, which closes the split. The dead-center has also a fine adjustment by a milled head on a screw, this having also a split clamp. The vertical and back and forth feeds are by hand. The transverse feed is from the cone-pulleys on the spindle to a complementary nest at the side of the standard. By two universal joints and a telescopic shaft motion is transmitted through a jaw-clutch to the bevel-wheel on the end of the feed-screw. This jaw-clutch can be disengaged by an adjustable stop on the table. It has all the usual and necessary attachments, to be alluded to in the sequel.

Fig. 290 shows a universal standard milling-machine differing from the preceding in several points. The bearings for the spindle are cylindrical, and the thrust of the mills is borne by composition washers on a step-screw at the tail. The journals are of bronze split at one point, and wear is taken up by capstan nuts on each side of the castings of the standard. The arm for outside center has a long cylindrical fit in the cap casting, with about

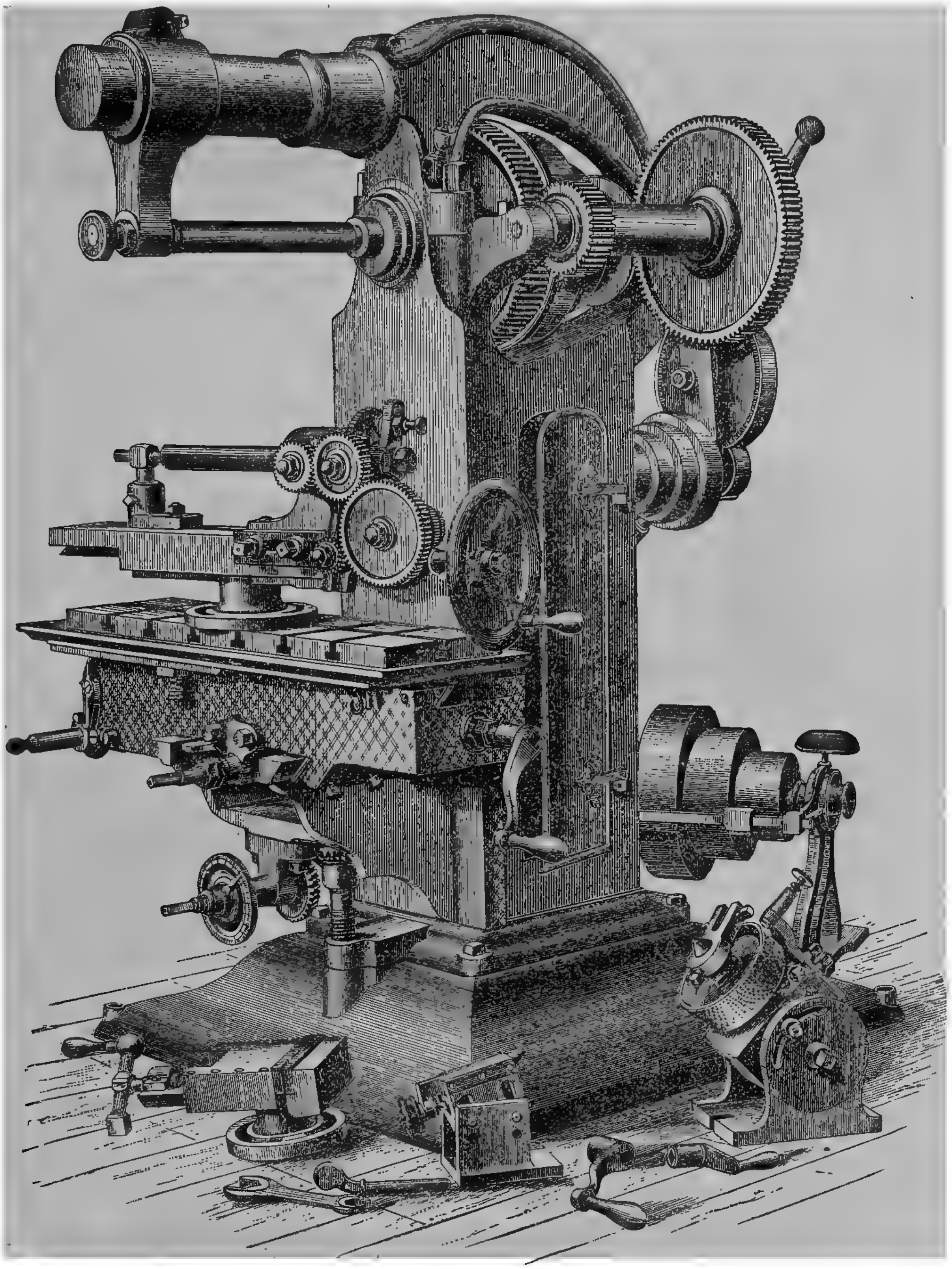


Fig. 290.

1 inch of thread. When screwed home to refusal the split is tightened to prevent the arm from jarring itself loose. The back-gears are at the side, and the feed-shaft is driven by shielded gear and belt through a floating cone-pulley shaft linked to driver and follower. Wear in the feed-screws can be taken up by double nuts. The same fine graduated motion to the table is obtained as in Fig. 282. The main spindle is hollow for convenience of driving out mandrels. In these tools of this class the workmanship is of the best and most accurate. The surfaces are scraped with the greatest care and regard for truth, and so accurately is the work fitted to gauges that in the T-slots in the tables a tenon gauge may be pressed in by hand, but must not fall in easily. From this exactitude in the machine it follows that its work can be correspondingly exact. Units which were formerly thought so small as to be rather in the field of the physicist are now of frequent occurrence in our workshops.

Fully to entitle these milling-machines to the term "universal" certain attachments are required to go with them. These will bolt to the top of the table in the T-slots, of which there will probably be one longitudinal and four or six transverse. The first of these will be a vise, which can swivel to any horizontal angle (Figs. 291 and

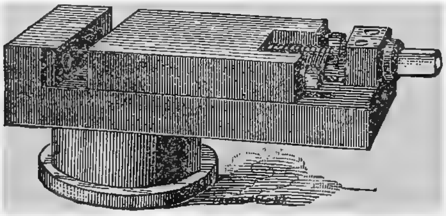


Fig. 291.

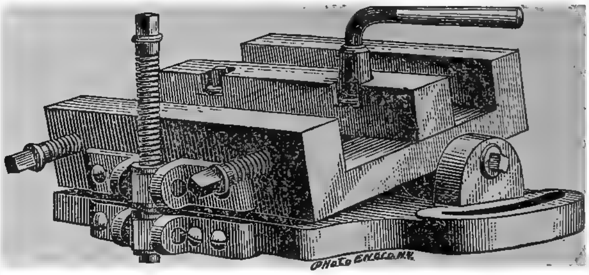


Fig. 292.

292), and one design permits vertical swiveling also. Any form of holder may be designed for any especial shape or process.

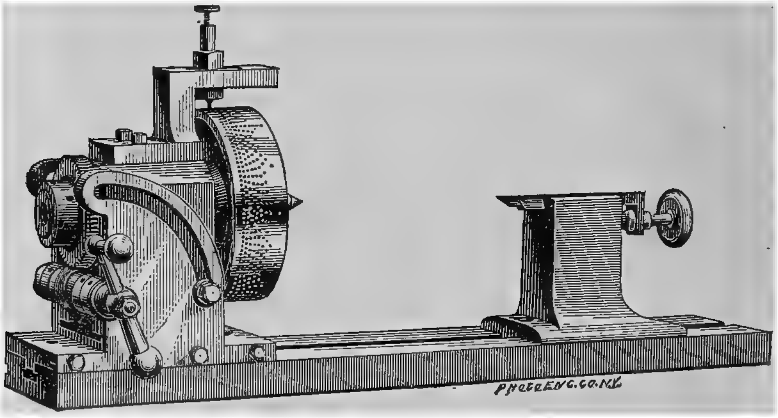


Fig. 293.

The second attachment is a universal head, which can also be used as a simple pair of centers. Fig. 293 illustrates a usual form. The head center is hollow, for rods of any length, and is fitted with a screw in front to hold a chuck or dog-jaw. The spindle may be revolved through any number of degrees by the tangent gearing, the divided cylinder in front serving as index and stop-gear. The whole center has a motion around the axis of the worm, by which an elevation may be given to it for working out tapers with a straight parallel mill. The stationary center has a short pin adjustment when clamped in place.

Fig. 294 shows a similar head with patent back center. The upright is faced on the inside, and fits the inner

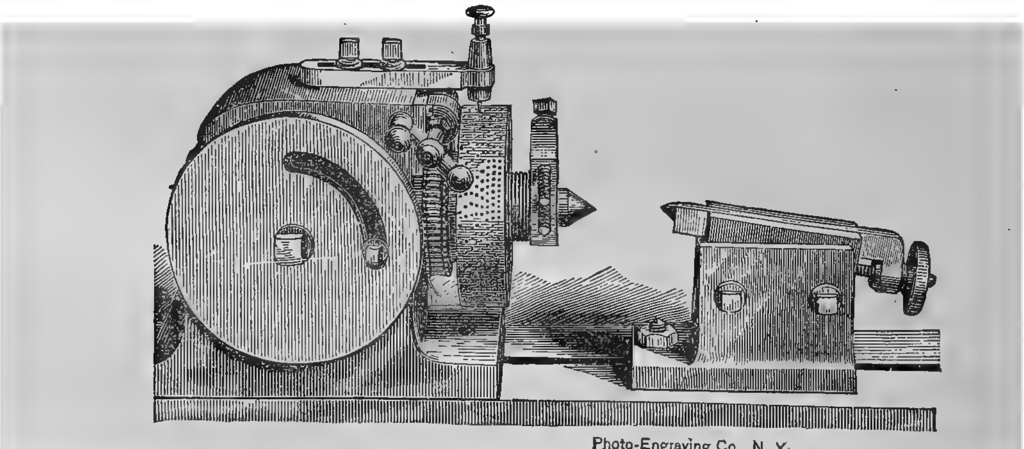


Fig. 294.

block, which carries the spindle proper. The two parts bolt together by bolts through the curved slots of the inner block. The center is therefore capable of elevation and depression, but can also be set at an angle, so that tapered work can be finished without danger of throwing the point out of the center line of the countersink and wearing both surfaces unduly. These heads will permit gear-cutting, both spur and bevel. The index-dial will divide in an average size of head all numbers to 25, all even numbers to 50, and several others up to 120. One large head has been made by these builders which will divide a circle into eighteen thousand parts with the highest limit of accuracy, and it will divide it even into fifty-four thousand parts. The worm-wheel is made with sharp V-threads,

and contains 180 teeth. The wheel is in two parts, and no matter how the two disks may be screwed together any two half-teeth form one without perceptible error. A graduated disk receives a spring pawl, by which exact record can be kept of the turns of the worm. There are arrangements to take up wear longitudinally by check-capstan nuts and vertically by hollow capstan-nuts on the block with through clamp-nuts.

The other attachment for the milling-machine table is a spiral cutter. While the work is fed longitudinally by a screw against the cutter, it receives also a motion around its own axis (Fig. 295). This second motion is derived from a worm on the screw by a train of change-wheels, and spirals may be originated and cut with pitches varying between 2 and 72 inches. The spiral may be cut upon a cone as well as upon a cylinder by a special device.

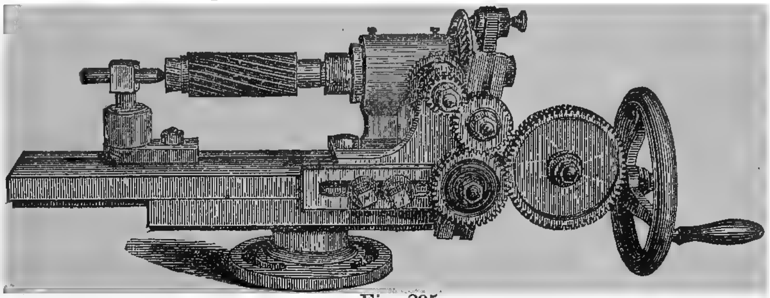


Fig. 295.

Of course for any special manufacture special appliances may supplement these standard attachments. With such devices the application of the machine to all kinds of work becomes most simple. Its use is extending, and is having a most important bearing upon exact manufacture.

§ 31.

SPECIAL FORMS.

For the use of drop-forging apparatus it is necessary that the steel dies be carved out to the exact shape desired. This manufacture of dies is called "die-sinking", and has given rise to a special form of milling-machine. Fig. 296

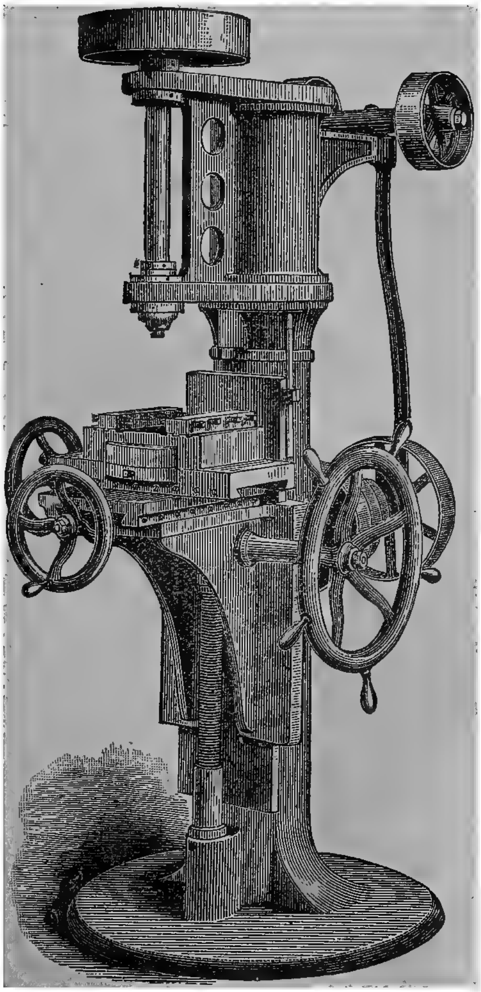


Fig. 296.

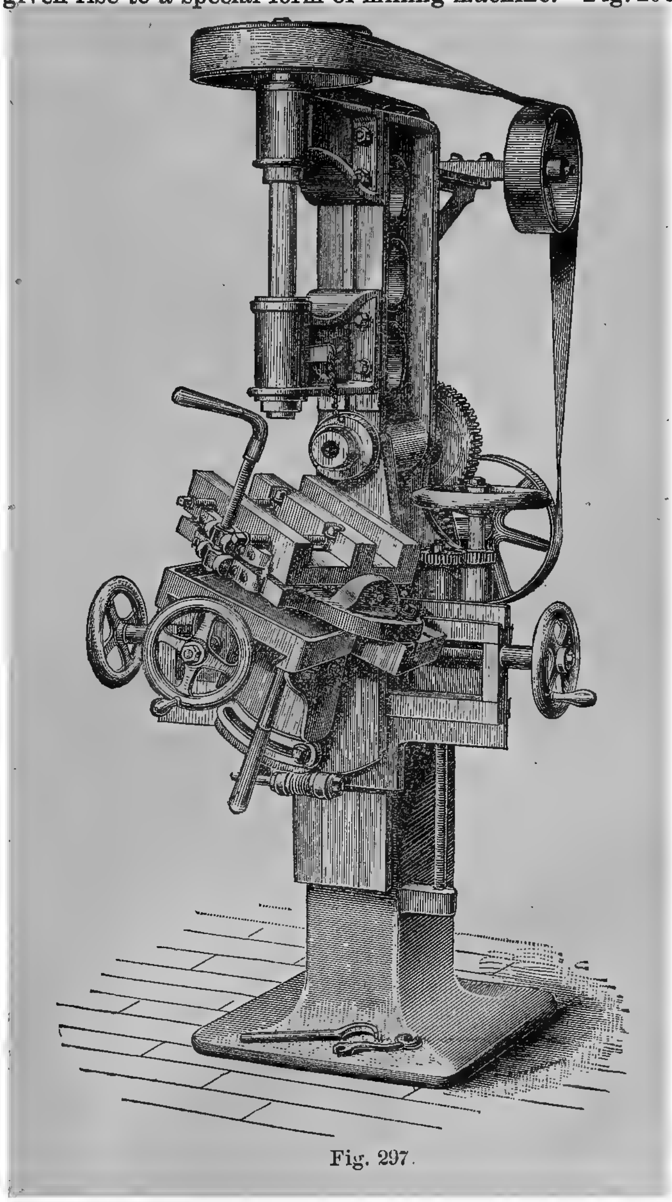


Fig. 297.

illustrates a type. The cutter is vertical, driven by a belt over guide-pulleys. The mill usually cuts on both face and side. The vise has compound motion by hand, and the knee-table can be raised and lowered. There are special devices for taking up thrust and lost motion at the bearings. Very often the motions to the table and vise are given by levers.

Fig. 297 shows a machine with both horizontal and vertical spindles and universal motion to the vise. A saddle has two motions in a vertical plane, and a swivel table, controllable by a worm, holds the slide which receives the vise. All the motions are controlled by hand-wheels within convenient reach of the operator. Such a machine, of course, can be used for any of the small work of miscellaneous milling.

For edge-milling or profiling the irregular shapes of several classes of manufacture the type of machine shown in Fig. 298 is approved. The pieces to be dressed are clamped to the table, which receives a backward and forward

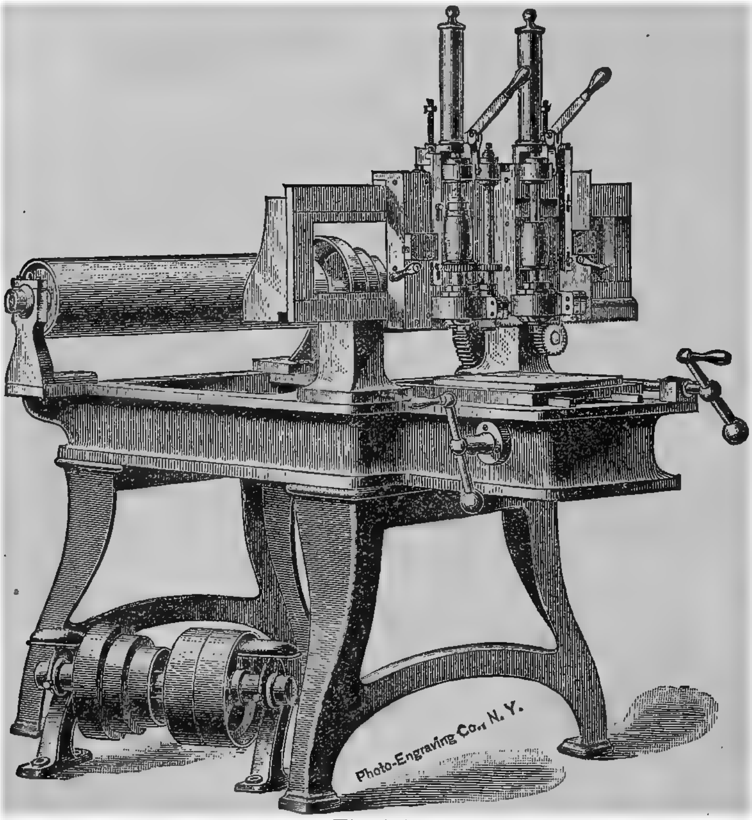


Fig. 298.

feed by rack and pinion from the ball-handle. The mills are carried in the vertical spindles, which are borne on a saddle, which receives transverse motion by a pinion on its under side through the ball-handle on the right. A former is secured to the table, and the operator controls his two feeds by that. The spindles have vertical motion by the hand-levers between adjustable stops for depth, and are driven from the long drum at the rear. This machine has a patent device for cutting formers without reversing the fixtures. The guiding-pin may be driven by gear from one spindle, and the cutter and pin exchange places, while the model is secured to the place which the work is to occupy in the future. The cutter on the guide-pin cuts the forming pattern in the exact position it will retain in use. The gearing and rack are made double, so as to be adjustable to prevent any back-lash in the feeds. This is essential for accuracy of irregular work, and especially in turning corners. Such a machine can also be used as a jigging and die-sinking machine. There may also be three spindles. A rotary cutter has been mounted upon an arbor transverse and parallel to a planer bed, and is used to mill out the flats of locomotive-rods. It is then known as a slabbing-machine, and will take a 4-inch cutter the full width of the rod. For cast iron a larger cutter may be used with advantage. Where, however, heavy work is to be done, the use of inserted cutters is expedient. The work done will then be proportional to the number of cutters, as compared with reciprocating tools.

An example of the economic application of this principle is shown by Figs. 299 and 300. The tool (Fig. 299) is designed to face off the ends of bridge and other girders to exact dimensions. The work is bolted to a stationary table, and the mill traverses in front of it. Several may be secured at once, and each is held independently by a set-screw through the clamp. The mill consists of a solid wrought-iron disk of tough and homogeneous metal. It is 2 inches thick and weighs 400 pounds. Eighty-four teeth are inserted in the rim, on edge and face alternately, and since the disk is 28 inches in diameter the alternate system permits a tooth upon every inch of circumference. The teeth are of steel, $1\frac{1}{8}$ inches face by $\frac{7}{8}$ of an inch thick, and are fitted in milled grooves. The milling-disk is

driven by a large steel worm on a splined shaft, by which a vertical adjustment of the slide is possible. The whole head is fed along by a screw either by hand or by power, through a worm-gear from cone-pulleys, and the feed can

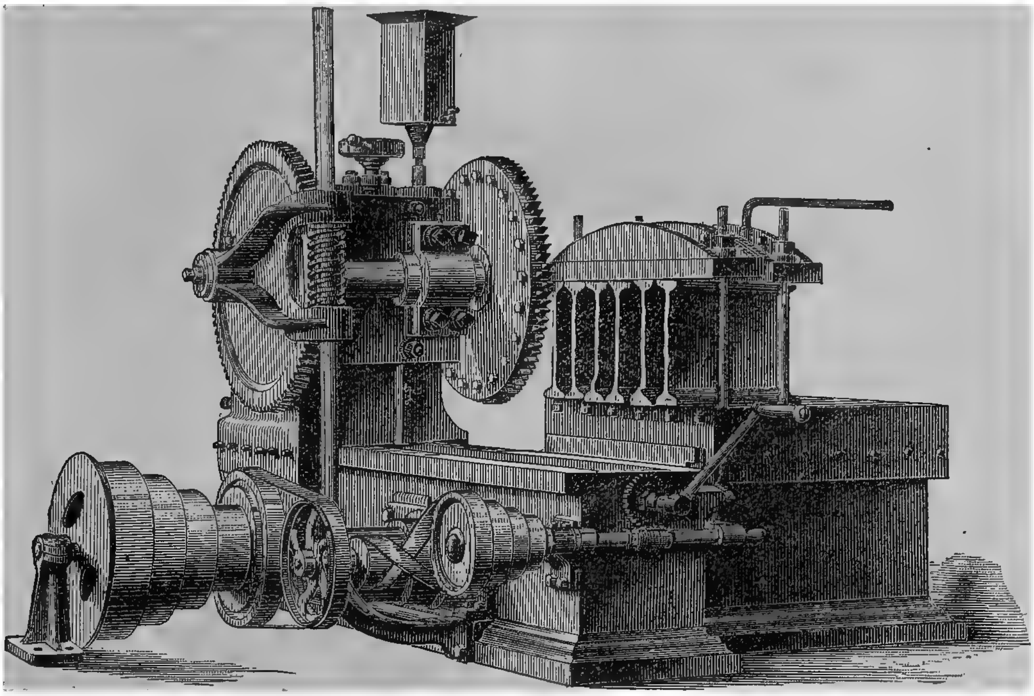


Fig. 299.

be varied from $\frac{1}{8}$ of an inch to 1 inch per revolution. Such a machine can square and finish six 15-inch beams per hour, allowing $\frac{1}{2}$ inch of metal to be cut from each end. If less is taken off the feed may be more rapid. In Fig.

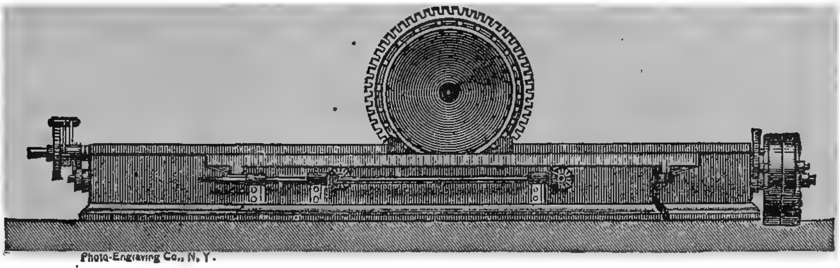


Fig. 300.

300 the cutters are twenty-eight in number, on a 25-inch plate wheel, which is banded with wrought iron. The wheel is driven as in the other tool by worm-gear, and the whole head is made to travel by an automatic variable feed.

§32.

GEAR-CUTTERS.

Any of the universal millers can be used as gear-cutters by means of a universal head, with worm-wheel and index. They can usually cut both spurs and bevels. There are certain tools, however, which are built for that especial purpose, and may properly be discussed by themselves.

Fig. 301 illustrates the type which has been in very general use. The blank from which the spaces between the teeth are to be cut is held firmly upon the end of a vertical arbor. Upon this arbor is secured the index-plate, with its stop-pin, adjustable legs, and clamp. The cutter is borne upon a slide which has a power-feed across the face of the blank, and the whole upright has adjustment for different diameters of blank. To compensate for the motion of the cutter-arbor the belt passes over a hinged binder-frame overhead, which is weighted to maintain a constant tension on the belt.

Fig. 302 illustrates a standard type of machine. The cutter-carriage is swung from a fulcrum on the standard, and may be set to cut bevels of any angle. The cutter is fed automatically across the face of the blank, and has a stop-gear. The mandrel for the blank may be adjusted for different radii of wheels. The wheels are divided by a worm-wheel.

To increase the adaptability of the milling-machine for bevel-wheels such machines as Figs. 303 and 304 have been produced. In Fig. 303 the index-plate is attached to the bottom of a hollow spindle, which swivels around a

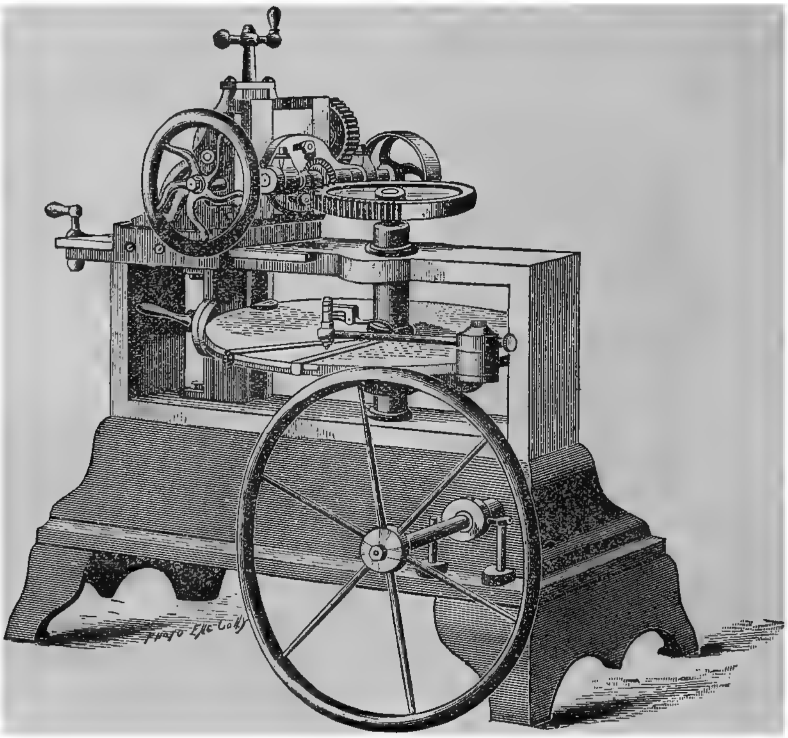


Fig. 301.

center on a vertical slide. The spindle can take a vise or centers or any attachment, and can be set at any angle between 0° and 180°. The vertical slide has a perpendicular traverse of 2 inches and a horizontal adjustment between stops for different diameters. The machine can therefore cut spurs and bevels and worm-teeth. The cone-spindle has a horizontal movement by hand-lever limited between check-nuts.

In Fig. 304 the mill-arbor is driven by bevel-gear from the splined shaft to avoid the necessity for the binder-frame. The vertical spindle has the same motions and adjustments as in the previous machine. As this is designed for general work also, the vertical spindle is arranged to clamp so as to relieve the index-plate from strain, as in the preceding type.

Fig. 305 illustrates a machine specially adapted for racks. The cutter is borne on a horizontal slide driven by gears from the cone-pulley, and more than one cutter may be used at once. The cutters are fed forward by power automatically, and the pitch for the rack is given by a spring stop into the teeth of a change-wheel. The train can be so arranged relative to the pitch of the traverse screw as to have the two pitches commensurable, and the pin should pass over always the same number of teeth.

In the best practice for larger wheel-work the drilled index-plate is replaced by a large worm-wheel, and motion to the worm is transmitted from a crank by a train of change-wheels, as in Fig. 302. The crank is arranged to lock with a spring latch or by a jaw of some sort, so that any number of entire revolutions of the crank may be so multiplied or divided as to effect any subdivision of the circumference of the worm-wheel. By this means the errors of fractional subdivisions are avoided, and also possible inaccuracies from the division or wear of the index plate. Moreover, when the worm-wheel is large, any errors in it are reduced in cutting-wheels of smaller diameter than itself, which will always be most numerous. The only source of error is from the danger of making the wrong number of turns of the crank-shaft. The combinations and numbers of turns can all be worked out and tabulated in advance.

The most advanced types of gear-cutters are those which are automatic. They are made by several of the best builders, and after adjustment of the blank and the combinations they will operate without supervision from the attendant. It is therefore possible to keep four machines full and earning their own interest, with the cost of the labor of but one operator to be divided among the four. Beside, the automatic machine is likely to work more rapidly than a similar machine worked in part by hand. There is a general resemblance in the mechanical devices for securing automatism, though the machines differ widely in outward form and appearance and differ in their adaptedness for large and small work.

A Providence machine for wheels up to 18 inches diameter, with 3-inch face, is shown by Fig. 306. It will cut wheels of any angle by the sector adjustment of the cutter-slide, which carries a graduated arc and index. The cutter-mandrel is driven by belt, with idle-pulley, for equality of tension. The wheel is secured on the horizontal

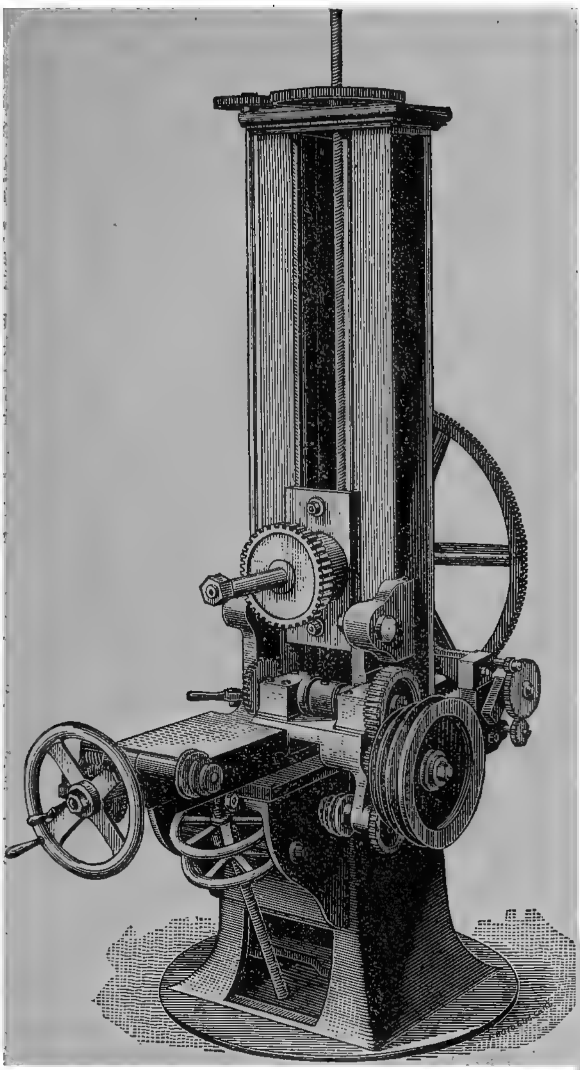


Fig. 302.

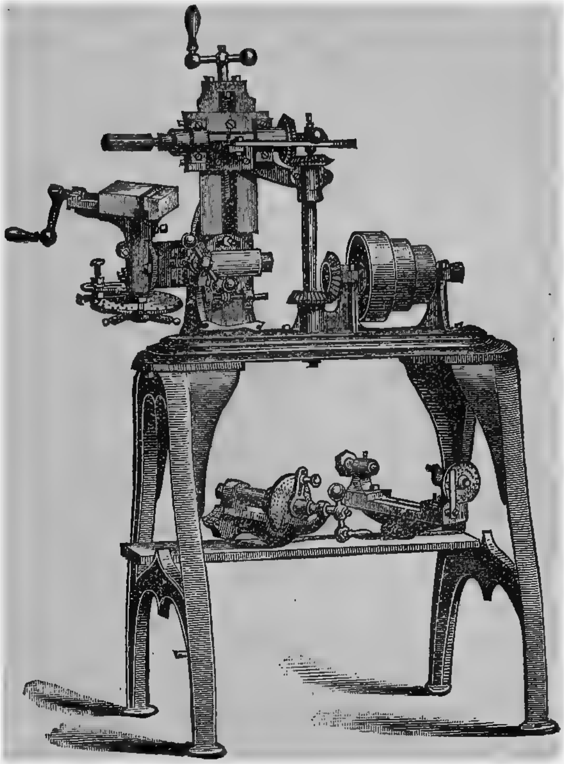


Fig. 304.

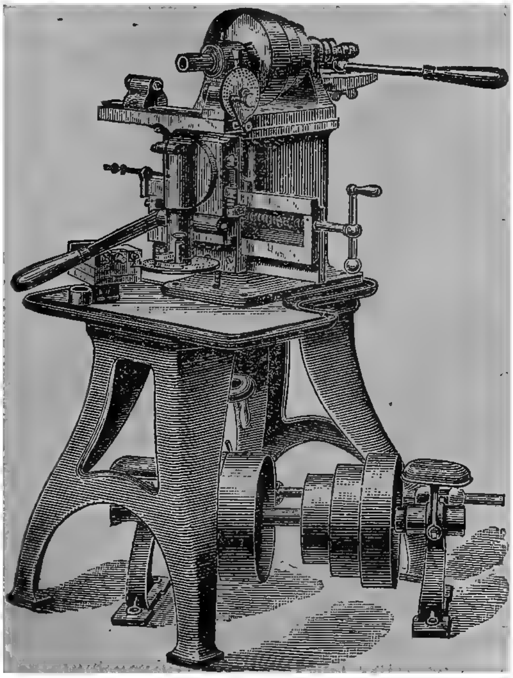


Fig. 303.

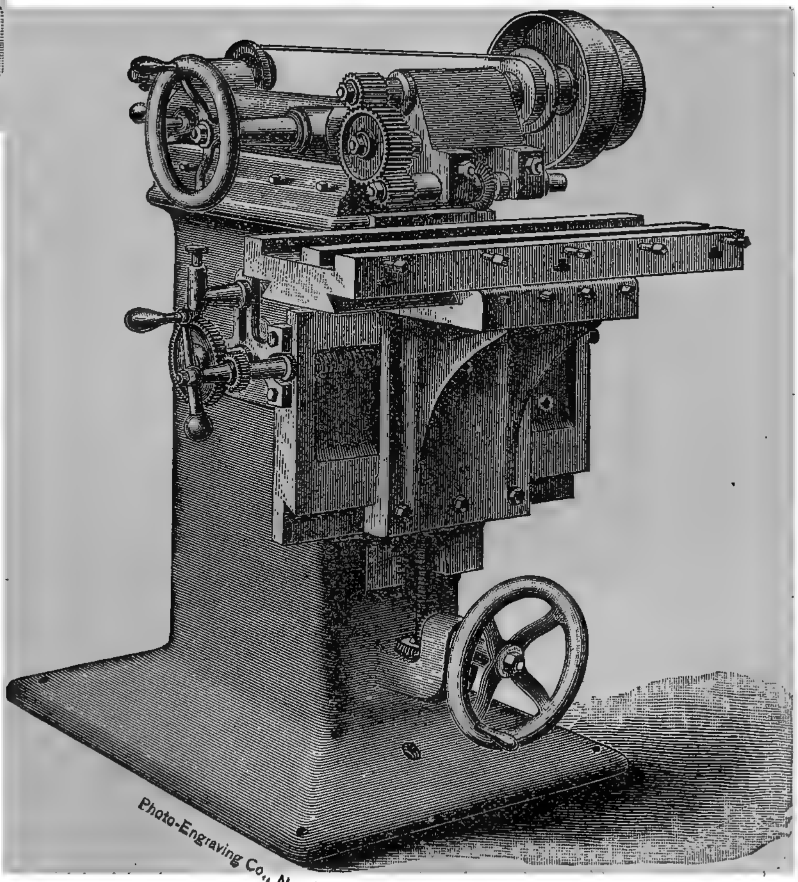


Fig. 305.

arbor, and the latter is adjusted by a scale graduated to thousandths of an inch for exactly the proper depth of tooth. The cutter-slide is fed forward by a screw at the proper speed, cutting through across the face, and when the cut is made the slide returns at quick speed. This is effected by a clutch between bevel-gears on opposite sides of the driving-shaft, and of different diameters. The shifting-device is prevented from stalling by wedge-points, one on the clutch-lever and one on a movable stud pressed forward by a spring. As the two wedges cannot hold by their sharp edges, the compressed spring will certainly throw the clutch to one side or the other. To give the proper rotation to the blank, that the next cut may be properly made, the mandrel carries a worm-wheel. The worm which drives it is borne upon a splined vertical shaft, driven from below by change-wheels. The spline permits adjustment for wheels of differing diameters, and the worm is turned and locked by a special device. When the cutter-slide has retreated it engages a clutch, which puts a train in motion, turning the worm. On this clutch-shaft are two wheels, side by side, with their faces plain, except a notch in each. One wheel is fast on the shaft; the other is loose, and is driven in the direction opposite to that of its mate by internal gearing from an idle shaft. It is obvious that a detent can only fall into the notch of either wheel when that of each shall coincide under it. This detent can be so shaped as to lock both wheels and to disengage the clutch which is driving them. Since the wheels are driven in opposite directions, it is simply necessary so to arrange a train of change-wheels that the two notches shall coincide only when the proper number of revolutions of the worm shall have been made. When the shaft has gone round the standard number of times, the notches coincide, the detent falls into them and locks the worm-wheel and blank, and disengages the driving-gear. The detent is loosened by the return of the cutter-slide.

In one of the Philadelphia designs the worm-shaft is driven by a train of change-gears, which must change the speed of the driving-arbor by proper alteration of the six revolutions which the latter always makes when engaged by the return of the cutter-slide. This series of six revolutions is secured by the action of dogs upon two equal wheels with different numbers of teeth.

Fig. 307 shows a special automatic pair of machines, one for spur-wheels and the other for bevel-wheels of small dimensions for light machinery.

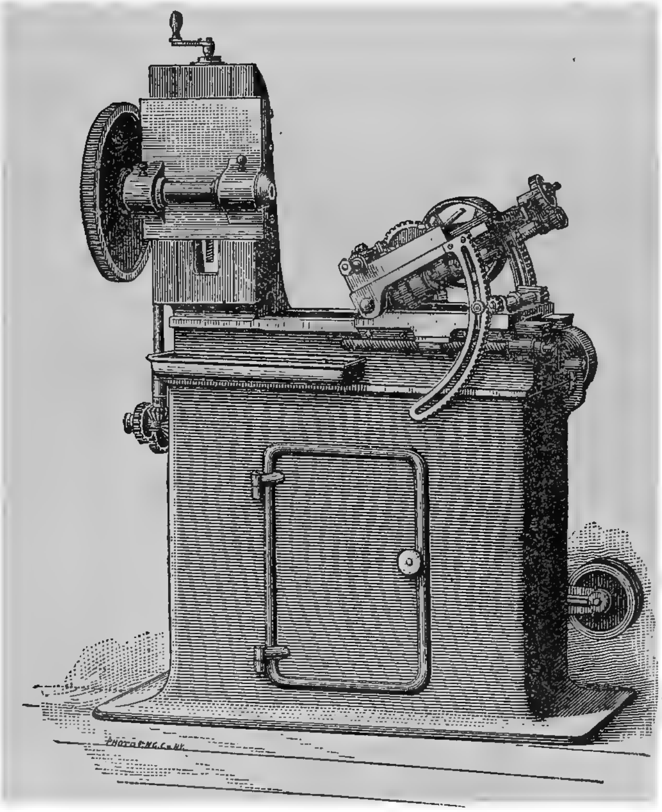


Fig. 306.

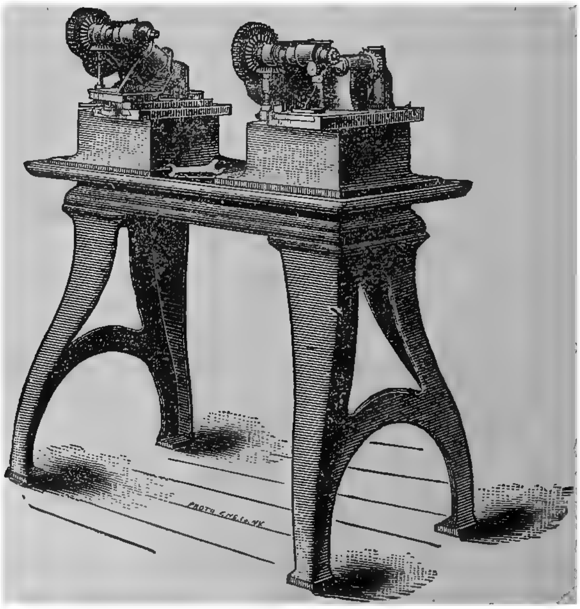


Fig. 307.

Figs. 308 and 309 *a* and *b* illustrate a large automatic machine for bevel- and spur-wheels up to $4\frac{1}{2}$ feet in diameter and of 12 inches face. It will divide the circumference of wheels containing from ten up to three hundred and sixty teeth. The cutter is borne upon a horizontal slide, with variable traverse and return motion. It is driven by bevel-gear from the cone of belt-pulleys, the belt passing over a counter-weighted tightener-frame. The feeding and dividing motions are obtained from the central vertical shaft. By supporting the outer end of the mandrel for the blanks a large number of thin wheels may be cut at one cross-traverse.

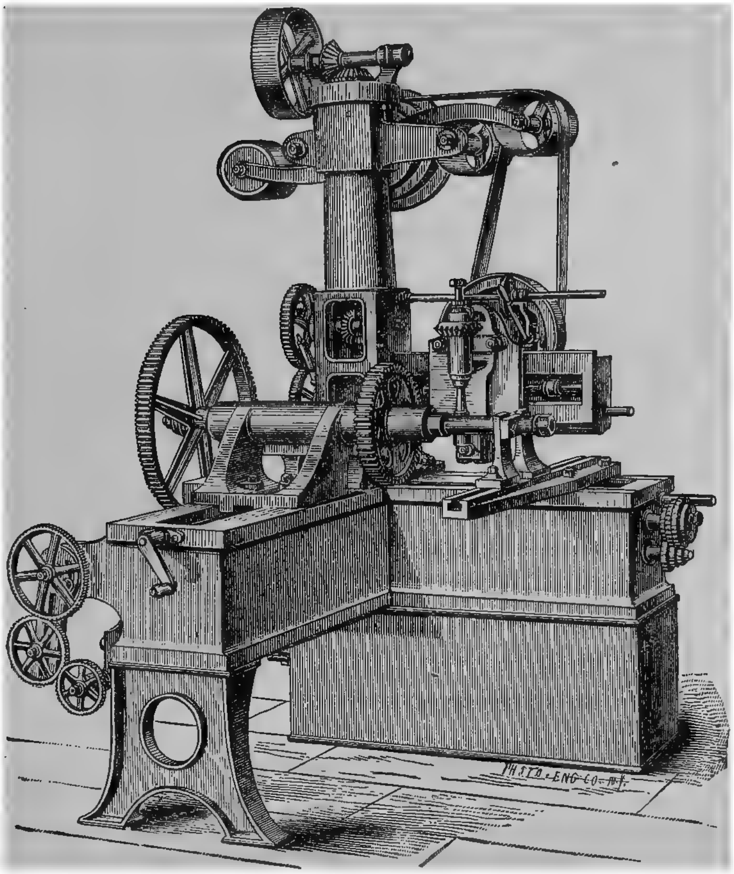


Fig. 308.

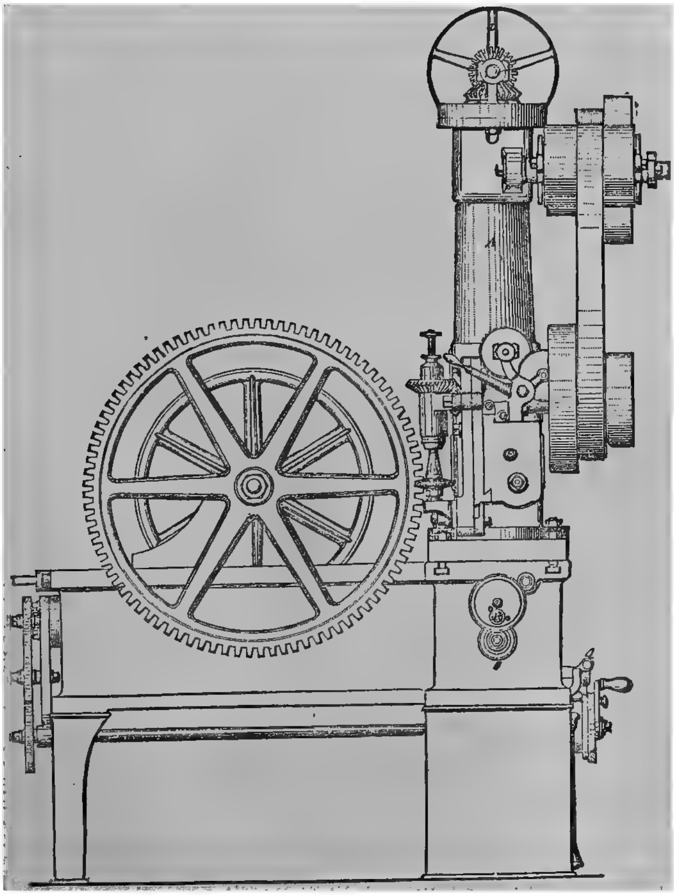


Fig. 309 *a.*

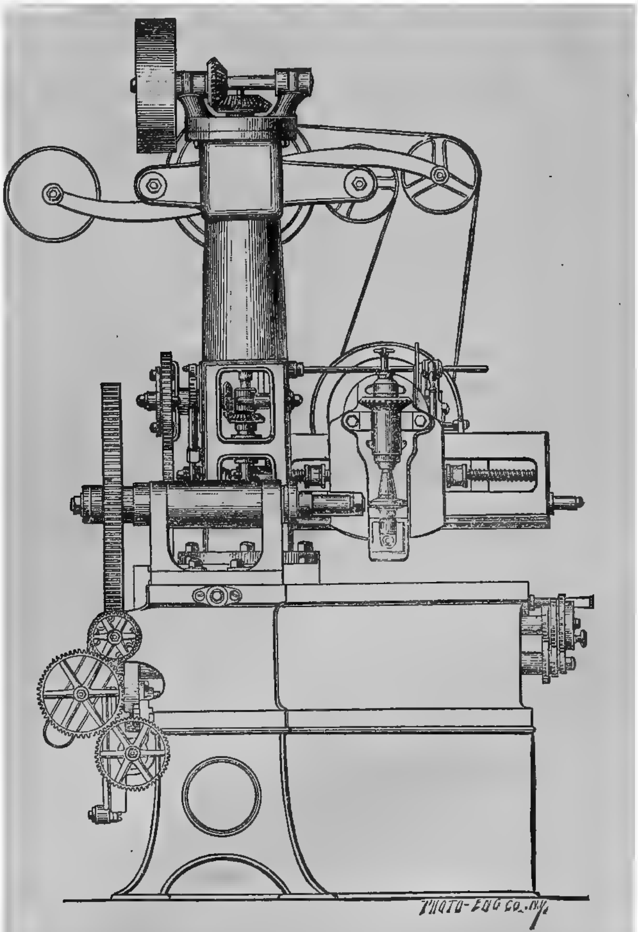


Fig. 309 *b.*

For the rotating cutters for these machines a very general type of patent cutter is shown by Fig. 310. Such cutters are so constructed that they can be sharpened by grinding upon the flat front face without spoiling the profiles of the side edges. The relief necessary for the top of the cutting-face obliges the profile to retreat toward the center. If only the top retreated, each successive grinding would make the space cut in the blank more and more shallow. To avoid this, each cutter is turned in a relieving lathe. The forming-tool receives a special forward motion from the tip to the root of each cutting-tooth as the mill being shaped revolves on a mandrel. This forward motion is imparted by a cam under the former-slide, which revolves once for each cutting-tooth of the mill (Fig. 311). To make the forming-tool, the true profile is worked out and a male chisel is made from it. By this male tool a female tool is planed out, and this latter is used to turn the spiral profiles of the mill itself. By distributing the numbers of teeth in each circular pitch among eight cutters the errors from inexact profile are made quite small.

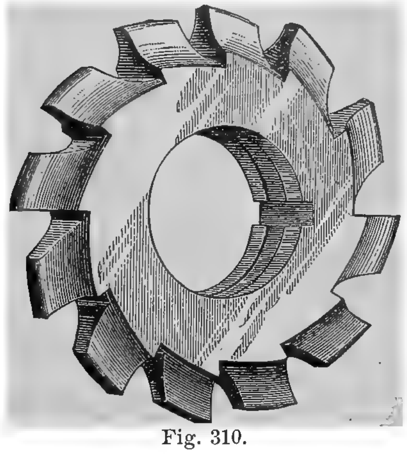


Fig. 310.

In another system (Pratt & Whitney, Hartford, Connecticut) an especial tool is used for producing an exact epicycloidal profile in the templet from which the mill is to be shaped. Fig. 312 shows a side view, and Fig. 313 gives a view in oblique plan. By this means is eliminated the variableness of profile of hand-made equivalents. From this templet, mechanically exact, as a former, the profile of the mill proper is reproduced. If the edge of a templet,

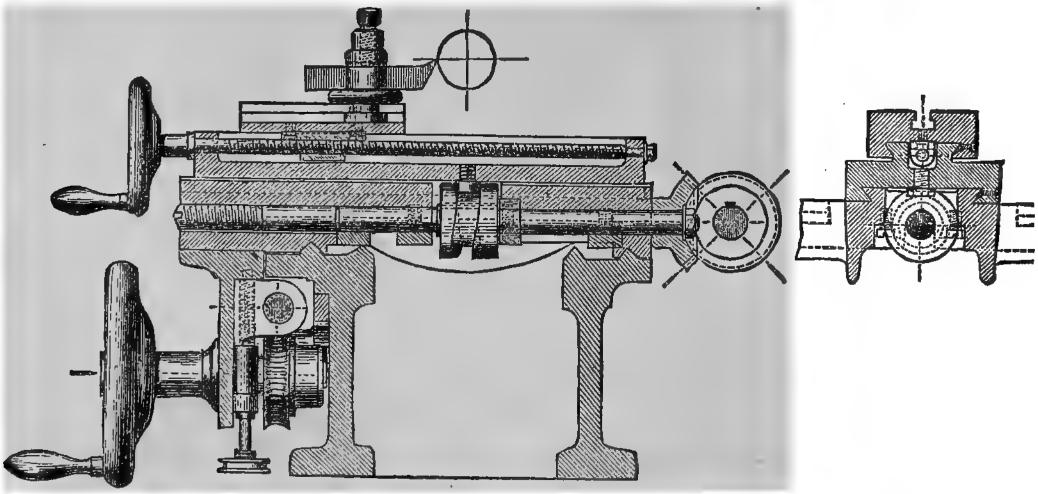


Fig. 311.

T T (Fig. 314), has been shaped by a cutter traveling on a true epicycloidal curve, a roller, P, running along the profile of T T, will make another cutter, N, on the axis of P, reproduce a profile, R S, which has a constant

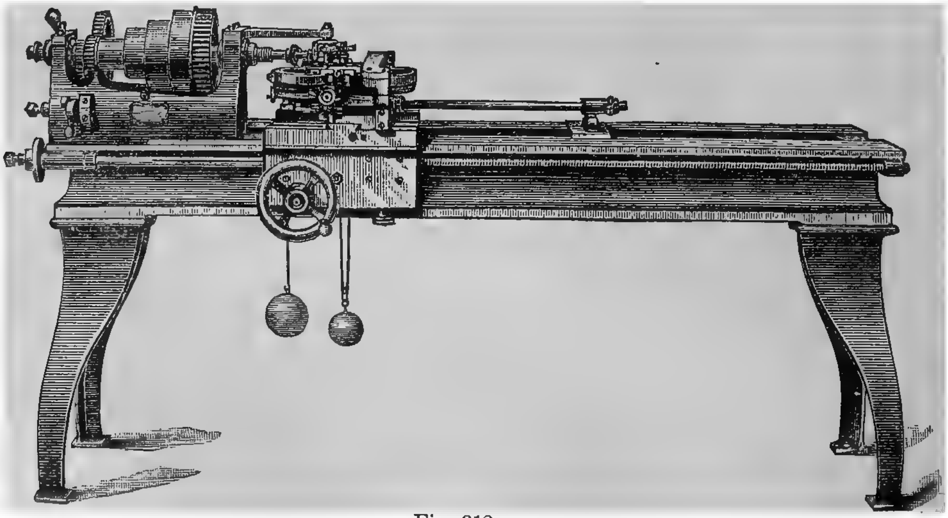


Fig. 312.

normal distance from T T. The reproduction of such curves for cutters is done by turning the cutter nearly to the required form and notching it for the cutting-edges. It is then put upon the pantographic cutter engine (Fig. 315), by which the exact profiles are produced for any other pitch by reduction with a simple device. The pantographic

engine will reproduce any type of tooth profile other than the epicycloidal, if supplied with the corresponding templets. This method gives exceedingly satisfactory results. It is open to the theoretical objection that even a roller of the same size as the original milling-cutter will not retrace completely the cycloidal path in which the

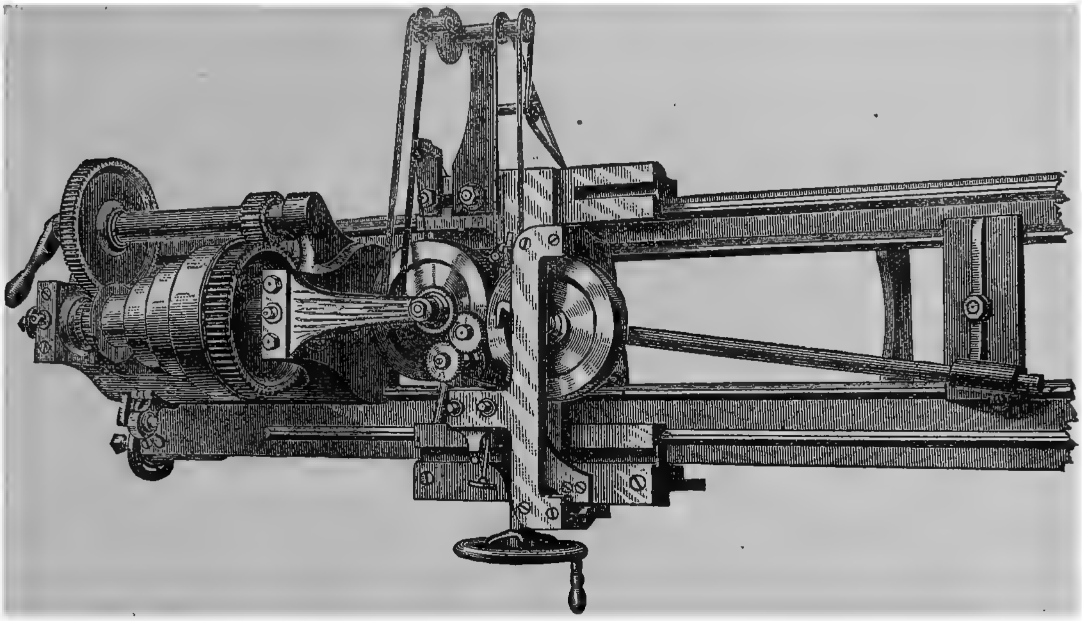


Fig. 313.

latter moved. But this objection is found to cause an inaccuracy of profile in practice so small as to defy detection. Very large wheels are always cut from a former, which guides the cutter. It becomes impossible to use a cutter which shall fully fill the spaces and reproduce itself in large pitches. Hence a cutter is used which dresses the profile by acting upon successive elements, with frequent traverses, and which is controlled by working up to a suitable former.

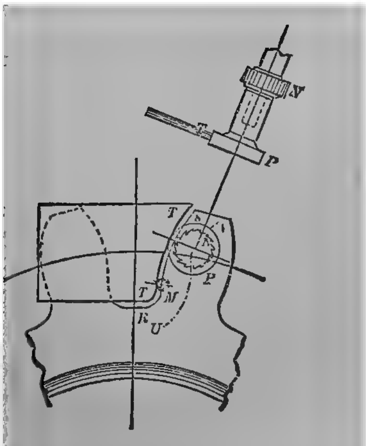


Fig. 314.

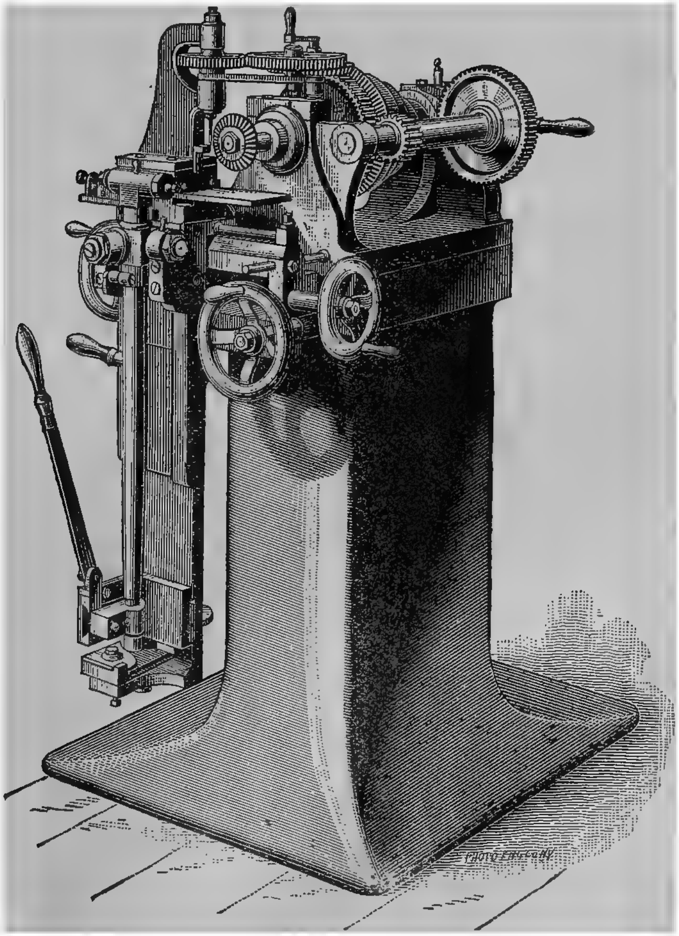


Fig. 315.

For bevel-gear the largest type of machine is that (Fig. 316) of Mr. Corliss, of Providence, Rhode Island. The blank is held upon a horizontal mandrel, on the end of which is an index-wheel of 15 feet diameter. By the use of such a large wheel any errors in it are reduced in the work. The blank is so secured that the apex of its conical surfaces shall coincide with the point through which the path of the tool-point always passes. By guiding the tool-slide by a large former, against which the rear of the slide shall be held, the path of the cutting-point at each

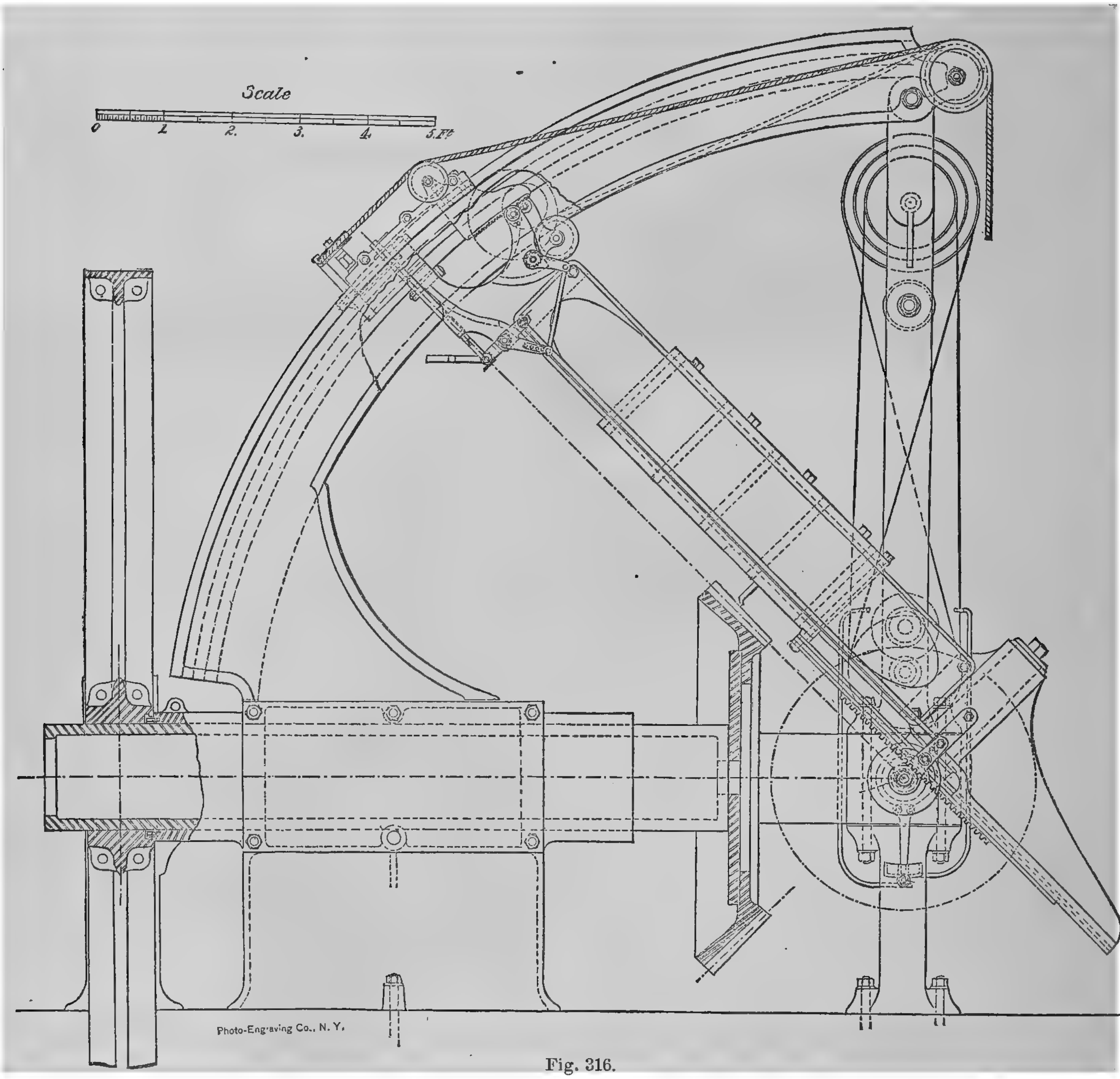


Fig. 316.

element of every tooth will pass through the apex and be tangent to an exact profile at the base of the cone of which the blank forms a short frustum. Profiles of great accuracy will thus result. A smaller machine on similar principle is built by the same makers.

Fig. 317 shows a gear-dressing machine by Gleason, of Rochester, New York. It will act on both spur- and bevel-wheels up to 100 inches in diameter. The wheel to be cut is mounted on the horizontal mandrel, which carries the worm-wheel and train from a crank. For iron wheels the tool-slide is driven by a crank from the central shaft in the upright post, whose center is the center of all cones in bevel-wheels. The end of the radial bar is laid off in degrees for convenience in this work. The tooth-former is put under the tool-holder, and the latter is fed over it. To dress wooden teeth inserted in rims or for patterns a thick circular saw is held in the tool-post, and is driven by belt over guide-pulleys from a radial drum overhead. The radial bar will swing to any angle with the mandrel between 0° for spur-wheels to 90° for crown-wheels. It is also hinged, to permit a vertical movement for bevel-wheels. With greater capacity than the preceding design, it is much less bulky and more rigid vertically.

Fig. 318 shows the Holmes machine working upon a similar principle.

While these latter machines scarcely belong to the class of milling-machines, yet they attach themselves so closely to the milling gear-cutters as to be presented at this point.

The milling-machine in its larger sizes, for locomotive, pump, and engine shops, is becoming increasingly popular. While at present practical considerations often overweigh the theoretical advantages which the tool possesses, and which would lead to its introduction, yet the tendency is toward higher appreciation of the value of

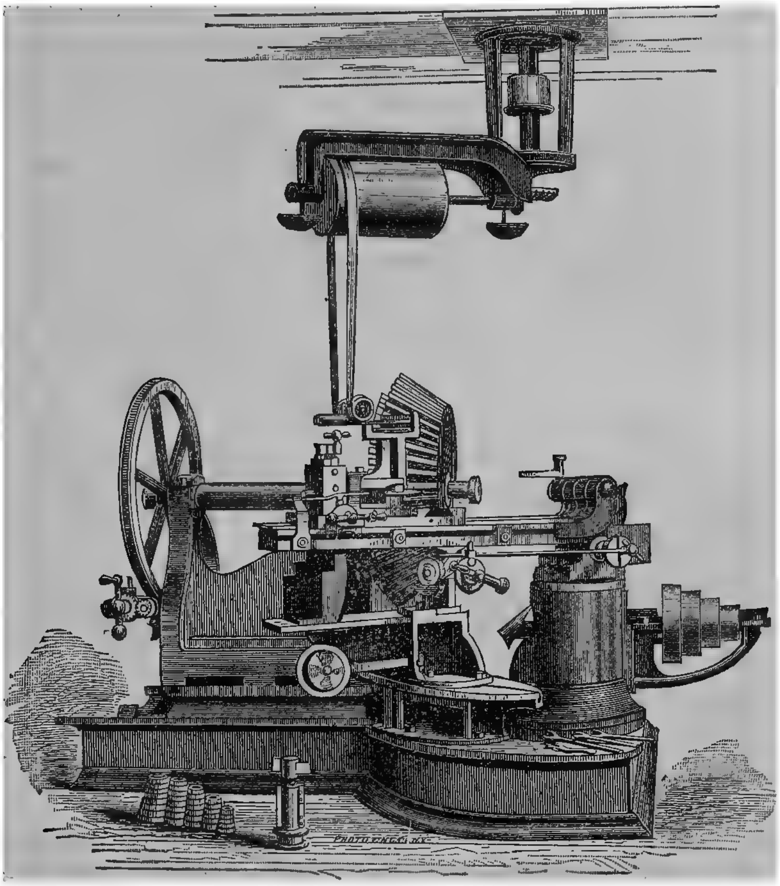


Fig. 317.

the tool. It may also by comparison be called a distinctively American tool in the forms in which it is most frequently met, because the greatest improvements in it have originated in the genius and necessities of this country. By its means production of certain specialties has been cheapened to a degree which would at one time have seemed entirely impossible with the existing high prices of skilled labor.

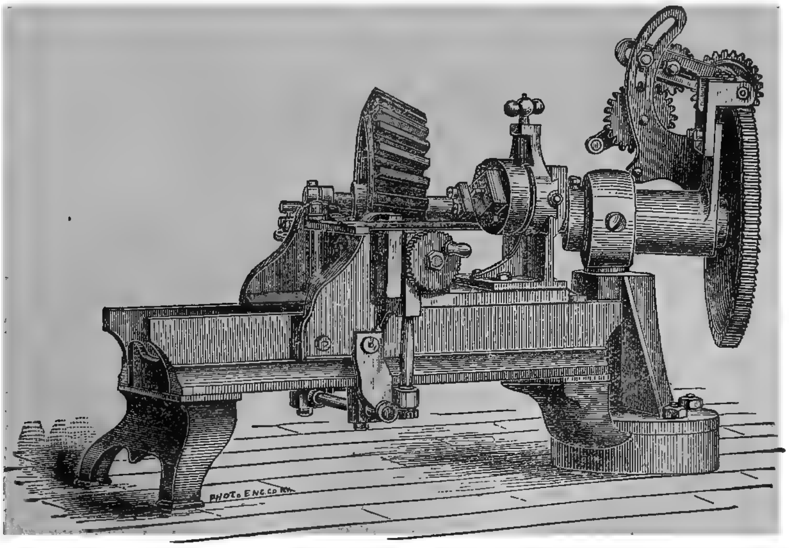


Fig. 318.

§ 33.

E.—TOOLS ACTING BY ABRADING OR GRINDING.

To this class belong the machines in which the conversion of material is not effected by cutting-edges of hardened steel, but by the attrition of revolving mineral. The work is presented to it, and the sharp particles of the stone abrade its surface. The abrading mineral is either the grindstone grit, emery, or corundum, and it may act to produce an especial shape of work or simply to produce a finish or polish on work already shaped.

A very large part of the duty of these grinding-tools is the production of cutting-edges upon hardened steel, that the softer metals may be cut by them. This shaping of the edges or sharpening of tools is the especial function of the grindstone. It is employed to smooth and polish in but few industries. The sharpening grindstone is held between flanges by a nut on a mandrel. The wedges around the mandrel should be just sufficient to keep the stone from throwing, while the flanges serve to hold it in place. The stone should have a speed at the periphery, varying with the class of tool to be ground upon it, from 200 to 500 feet per minute. Where hard tools for wood are to be ground with light pressures, the stone should go faster than for metal-working tools, which will be held more firmly. To compensate for the reduction of diameter as the stone wears, by which the speed at the periphery will become too low, the belt-pulley on the mandrel should be changed for one of smaller diameter at proper intervals. To prevent the annoyance and danger from flying grit and abraded particles, as well as to keep the steel cool, grindstones are run with water. The stone stands in a trough, which holds the excess of water and receives the particles thrown off. It is not wise to let the stone stand or run in water, on account of the softening action of water on the surface. The water is usually delivered from a pipe upon the stone when needed, the supply being controllable by a faucet.

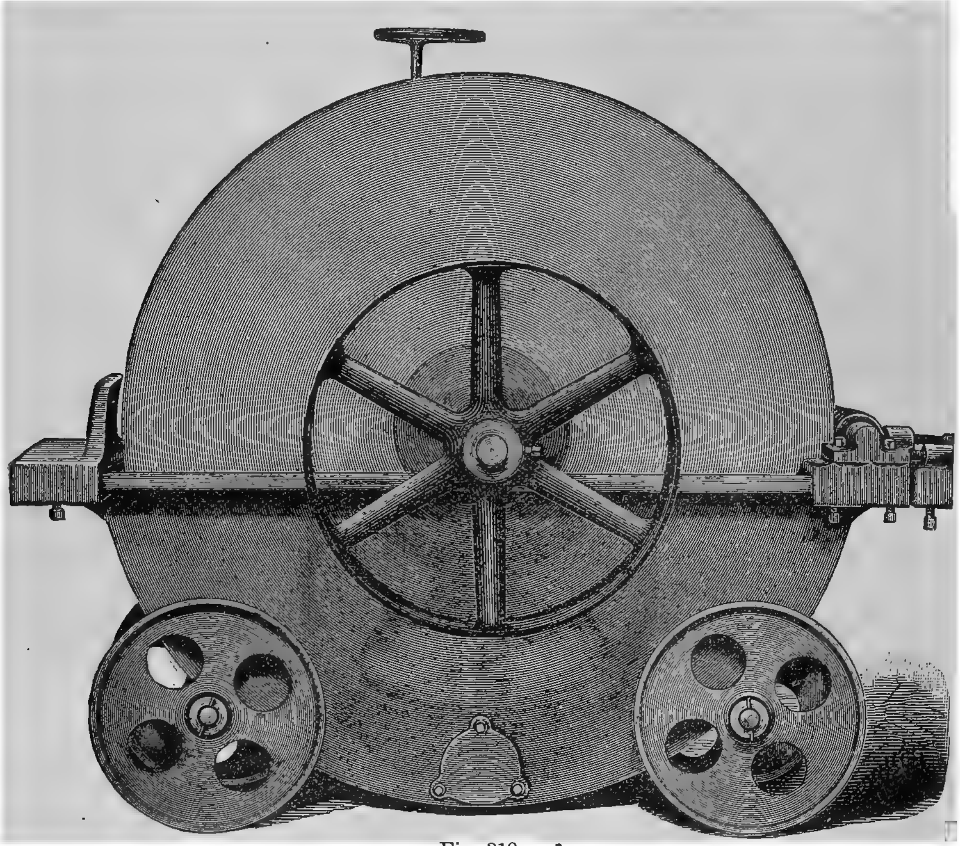


Fig. 319.

Fig. 319 shows a form of trough-mounting for a shop-stone. The stone is hung on a squared arbor, with long bearings, which are self-oiling and shielded to keep out grit. The boxes can be moved a few inches on the flat top of the trough, so that when the smaller pulley is put on after the stone has worn the belt need not be cut and re-adjusted. The rest is secured to the ledge of the trough by set-screws, and an adjustable self-turning attachment on the farther face keeps the stone round and its face true. This turning device consists of a steel screw, driven by the stone itself and pressed against it with any desired pressure by screws.

Fig. 320 shows a different design of mounting, the screw being linked to a hinge, so that the hand-wheel pressure easily engages or disengages it without special adjustment for equality of pressure upon the face. The water-can stands upon an upright at the side.

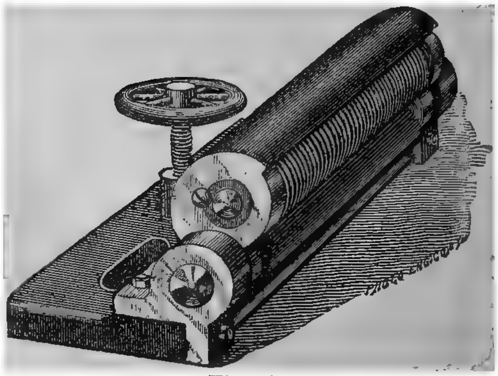


Fig. 320.

The modern grindstone-frames are mounted upon wheels. This has several advantages. The stand can be wheeled under a convenient crane or hoist, and the stone may be mounted or changed with ease. Secondly, when sufficient grit has gathered in the trough it can be wheeled to a convenient door or platform and there be hosed out through the hand-hole openings. By this expedient is avoided the overflow of gritty water, which may do harm, and is certainly untidy. In one design there are three wheels, the single one being swivel- or caster-mounted, in order that

it may be turned at right angles to the others and may resist the pull of the driving-belt. The wheel system further renders the maintenance of one belt possible with mandrel-pulleys of diminishing diameters as the stones wear.

Most of the grindstones in use come from Ohio or Michigan, or are imported from Great Britain or its colonies. They are of all grades of grit and hardness, which fact adapts them for the various purposes for which they are to be used. The fine, sharp grits are used for tool sharpening in shops.

Emery is used for tool sharpening in the form of the so-called solid emery wheels. These are molded disks of convenient size, made by cementing the ground emery to some vehicle which shall suitably carry it. These disks are mounted upon a mandrel and rotated at a high velocity. A usual velocity for average diameters is a speed at the circumference of 3,500 feet per minute. Small wheels often have a speed of less than 2,500 feet; larger ones are run at 5,000 feet or higher. While a large grindstone will remove a given quantity of metal in less time than an emery wheel, yet the emery-wheel can be made of a small thickness and of a shape which would be impossible in a stone. For milling-tools and for small machinery a wheel of small face will resist a lateral pressure which would crack a stone of same size and shape. The harder emery-wheel revolving at its high speed will do truer work also than the grindstone. This is independent entirely of the manufacturing capabilities of the emery-wheel, as in stove-plate work, wrought-plate work, fettling castings, small hardware, cutlery, etc.

The solid emery-wheel is an American invention. The special differences in the different makes arise from the qualities and defects of the cementing vehicle. This cement should possess certain properties. It must be strong enough in its cohesion to resist the centrifugal force due to the high speed of revolution. It must not soften, warp, split, or crack under heat or pressure, nor should it become brittle by cold. It must not dilute the emery too much by forming too large a percentage of the wheel mixture, and must permit such an intimate mixture with the emery as to produce a wheel of uniform density throughout with the same strength and texture. If it fails in this quality, the wheel will run out of balance in service, which is fatal to its usefulness and safety and durability. The cement must not glaze by fusion or combination with the cuttings, nor must it be so resistant as to make the work heat unduly from the necessity of wearing away the cement in order to get at the particles of emery. It would seem that an ideal cement to prevent these two latter difficulties would be one which wore away as fast as the crystals of emery lost their sharpness, so that the latter should be thrown off when their cutting qualities were lost. It will be seen, therefore, that the two conditions of free cutting and durability in a wheel are in a sense antagonistic, and the most that can be done is to effect a compromise. While, therefore, all should attain safety in use, durability and permanent sharpness cannot both be attained at once in any make of wheel.

Of the various cementing materials hard rubber or vulcanite was one of the earliest. Other makers use the gum from old leather acted on by acid, japan, and linseed oil, glue, silica with calcined chloride of magnesia, or "bittern" water, oil, and litharge, calcined chloride of zinc, celluloid and vitrified feldspar, or quartzose material. Most of these require the use of high hydraulic pressure in molds, a 12-inch wheel receiving a pressure of from 150 to 250 tons. One maker puts a circle of brass-wire netting in the center of the wheel to prevent accident in case of rupture. The same maker obtains the pressure for the mixture by the application of heat to the solidly-bolted molds. The hardness of the resulting wheel may be varied by the amount, by weight, of the mixture which is put in a mold of given capacity. The material undergoes a partial vitrefaction in the process of heating, by which the volume tends to increase. To secure balance in one make the four quadrants of the disk are filled separately, and are put in the mold in Russia-iron cells. Each of these is carefully weighed, so as to contain exactly the same weight of mixture when the cells are withdrawn. In the vitrified wheels the formed disk is exposed to a high heat in a kiln, by which the feldspar or its equivalent is partly fused and the wheel becomes as nearly like what a natural one would be as artificial means will admit. In one of these wheels the calcining makes the wheel porous, so that it is lighter in weight than when mixed. This permits the wheel to receive water at its axis and deliver it at its circumference, keeping the cutting-surface moist and cool without throwing an excess. Many of the wheels are fitted with a brass or lead bushing at the center, in order that a possible high temperature may not break the wheel by its expansion against a tightly-fitting mandrel. The wheels are held between flanges when at service, screwed up by a nut. It is often judicious to pad the flanges with leather, but is not essential with many makes. These vitrified wheels may also be run in oil for buffing or polishing work. More usually, however, this is done by wooden wheels, which are covered with leather on their face. The leather is coated with glue, and the emery is dusted on, or else the wheel is rolled in the emery. There are many of the cements which will not permit the use of water, and oil cannot be used on others. The glue wheels are likely to give off an odor in service.

To turn the emery-wheels to true cylindrical surfaces and to effect a complete balance the black diamond or bort is used. The wheel is chucked on a mandrel, and is faced on the periphery and on the ends. Any defect in balance is corrected by lightening the flat face. The wheels are graded by numbers. The lowest numbers, 8 to 10, give a duty about equal to that of a wood rasp; number 40 is about equivalent to a bastard file; number 80 corresponds to a smooth file; and 120 about equals a dead-smooth file. Flour emery gives a fine finish, without any especial sharpness of cut. The wheels may be molded and turned of any especial profile, as called for by varying classes of work. Some of these will be alluded to in the sequel.

Figs. 321 and 322 illustrate the ordinary form of emery grinder for general shop use. One carries two wheels, often of differing grades or profiles, with separate rests. One of the rests at least is arranged to act at the side of

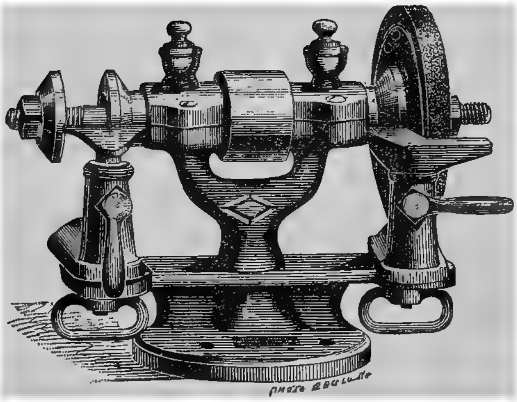


Fig. 321.

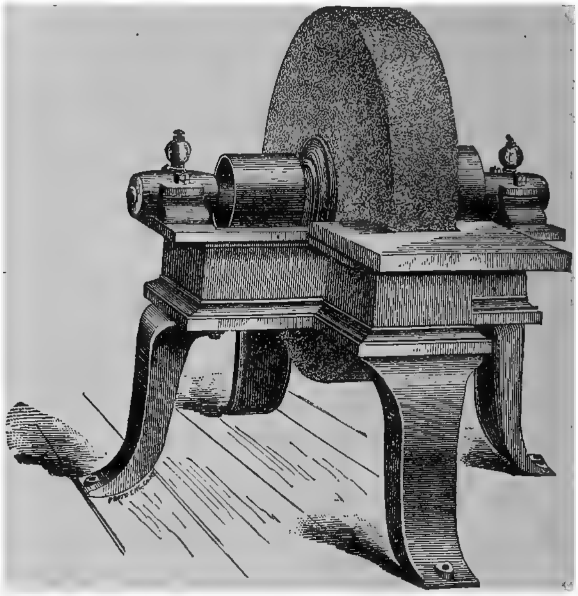


Fig. 322.

the wheel as well as at its face. One of the essential features of such machines is the proper protection of the bearing from the dust and grit which fly when the wheels are in use. In one design a ring outside the bearing is covered by a chamber in the long box, in which the grit will be caught.

Fig. 323 illustrates a compact standard grinder, with the self-lubricating boxes shielded by the cap. One of the wheels is plain, and the other is beveled for milling-gear cutters. A special attachment for cylindrical mills may be added.

Fig. 323.

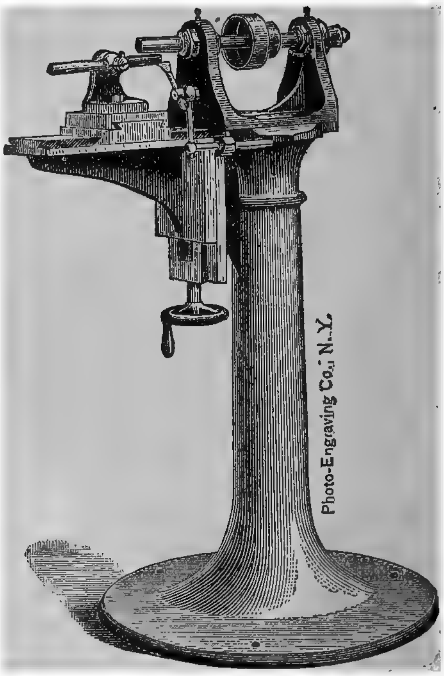


Fig. 324.

In Fig. 324 the grinder is especially designed for milling-cutters. A mandrel has a universal adjustment, vertical, lateral, and angular. An adjustable guide rests against the tooth which is being ground, by which the work may be gauged perfectly. Straight, taper, or spiral cutters may be ground with this machine, and it may use grindstones as well as emery-wheels.

Fig. 325 illustrates a douole emery grinder, with universal milling-cutter attachment. The bracket swings to any angle and may be clamped, and a guide secures accuracy. Work may also be held on centers or in a vise.

A convenient form of bench machine, holding the cutter on a mandrel between centers which are adjustable, is shown by Fig. 326.

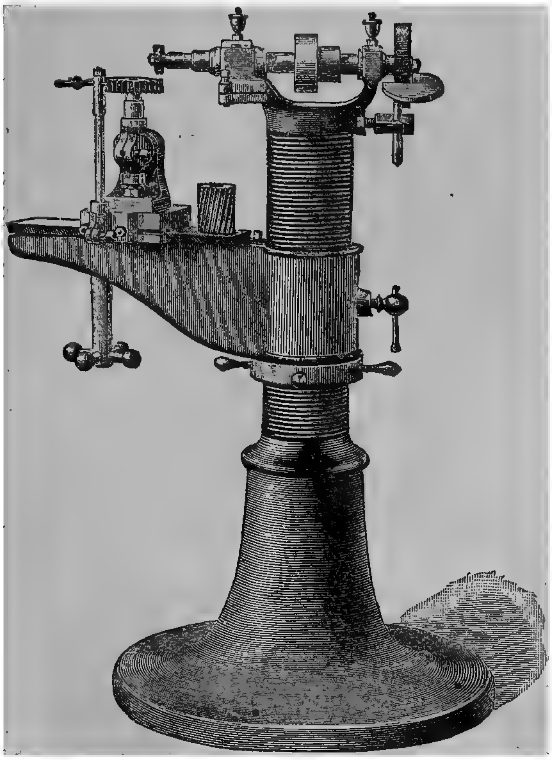


Fig. 325.

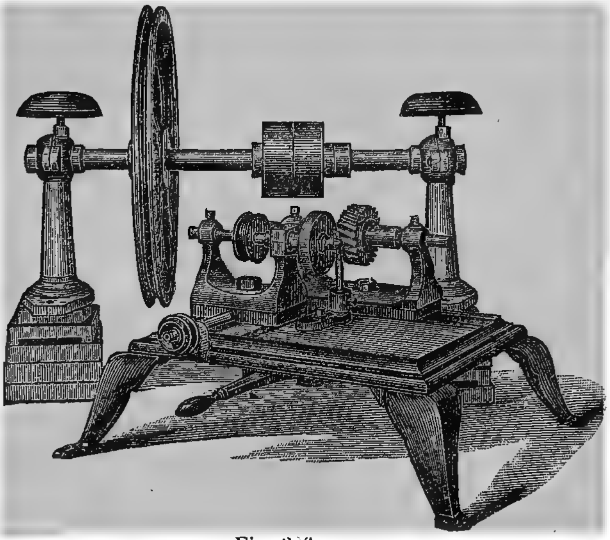


Fig. 326.

Of the special emery grinders perhaps one of the most important is the grinder for twist-drills. These should insure equal cutting duty on both edges and a proper relief or clearance while retaining them at a proper angle. Fig. 327 illustrates one form with the drill in position. The bar which guides the socket of the drill is placed at an angle with the horizontal traverse of the emery-wheel. This angle is experimental, and does not vary in the

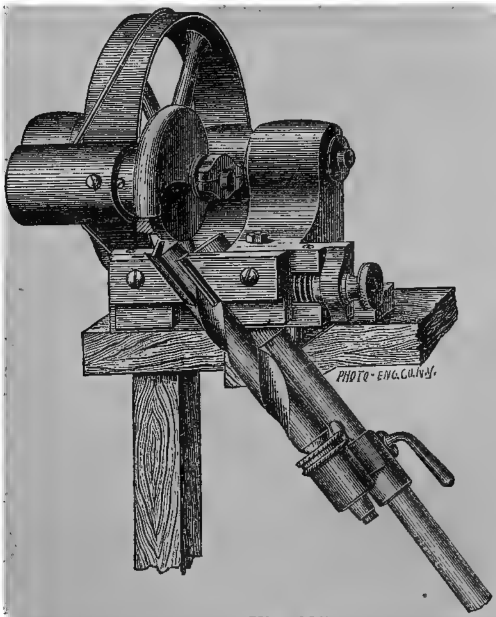


Fig. 327.

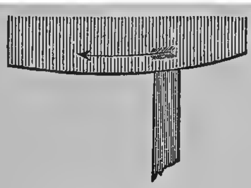


Fig. 328 *a*.

Fig. 328 *b*.

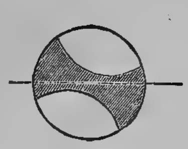


Fig. 328 *c*.

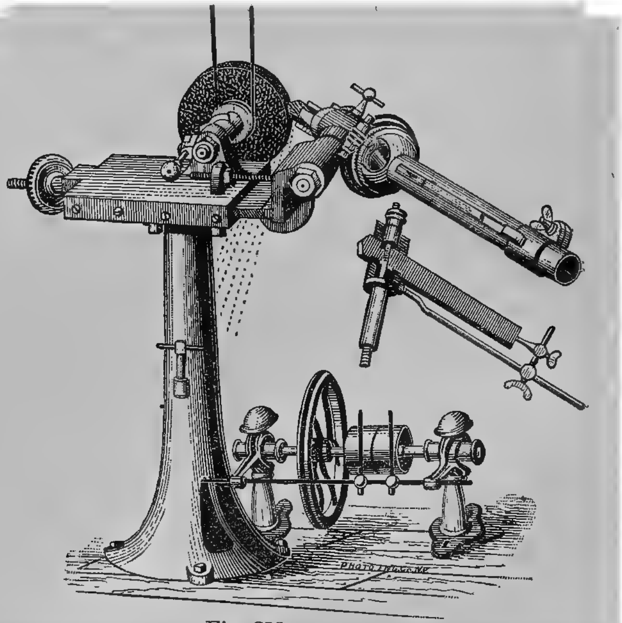


Fig. 329.

different makes very far from 45°. The drill is placed with its edge parallel to the path of the emery-wheel across the face, and receives clearance for its cut near the edge only. When one edge has been dressed to a true line the drill is turned on its axis through 180° by an index on the clamp for the socket. The vise at the lip is tightened anew, and the wheel makes its traverse.

For flat drills this tool gives all the clearance necessary (Fig. 328 *b*). Twist-drills require that the increasing clearance for the longer heel be given by hand, by backing off from the ground surface upon a second stone (Fig. 328 *c*).

In the machine shown in Fig. 329 the drill is held by a hollow spindle, which terminates in four jaws. These jaws are tightened upon the drill by worm and wheel. This spindle is attached to an horizontal arm which is not in its plane, making a projected angle of about 45° with it. This horizontal arm serves as center of motion for the spindle and the drill which it holds. As the lower end of the spindle is revolved upward the lip of the drill comes against the stone first. As the spindle is lifted further the heel of the edge is swung closer to the stone, and thus the relief is given. To secure equality in the two edges an adjustable stop abuts against the lower end of the drill, and the forward traverse of the emery-wheel may be controlled by stop-nuts upon a screw on the slide. The slide is moved by a hand-wheel. By this machine the lips of the drill will be of the same angle and length, will center in the axis of the tool, and will have clearance or relief increasing away from cutting-edge. This secures a durable edge to the drill, and the holes bored by it are more likely to be of the same diameter as the drill.

In the grinder shown in Fig. 330 the emery-wheel is a tub-wheel, which is a cylindrical wheel hollow in the

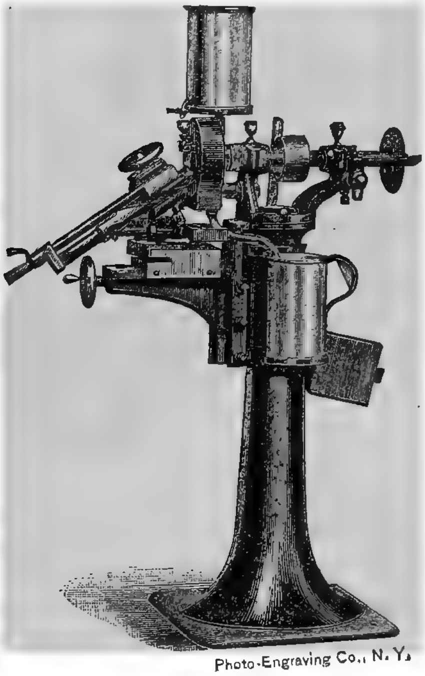


Fig. 330.

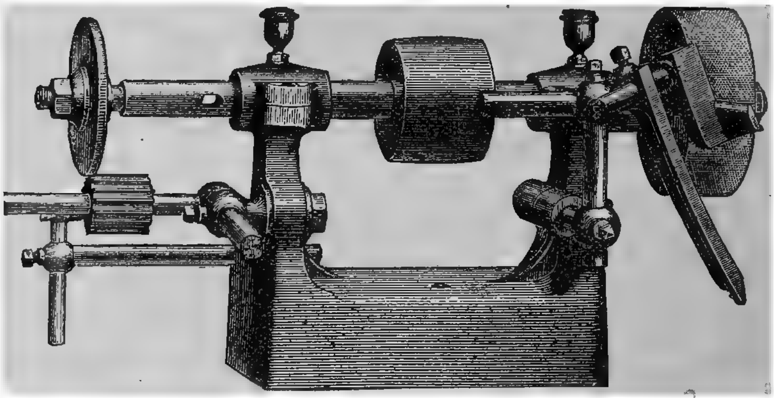


Fig. 331.

center, and which grinds upon the edge only. The builders prefer a vitrified wheel, which receives water in the middle of the hollow and delivers it to a drain below. The spindle is swung on a similar arm not in its plane at the proper projected angle. This arm is vertical. The drill is clamped by right-and-left screws, and the table which carries the vertical arm is moved toward the wheel by a feed-screw against stops for equal prominence of lip. The knee-table rises and falls by lever and counter-weight, so as to wear the face of the wheel equally. The edge is put vertical by a guide on the jam of the holder, and the amount of relief may be varied by loosening a large central screw. A similar machine with mill- or shell-reamer attachment is shown by Fig. 331. The articles to be ground are properly supported, and are presented to the stones by hand only.

Emery-wheels are also successfully applied for grinding the knives of wood-working planers and saws. Such a machine is shown by Fig. 332. The wheel used is known as a tub-wheel, which grinds upon the end only. By the use of this form the concave edge is avoided, which will be caused by the use of the face of a disk-wheel. Stop-gauges compel the knives always to stand at the same angle so as to receive the same bevel at every grinding, so that no unnecessary metal is successively ground away. The knife-carriage is fed back and forth by power. For sharpening saws the face of the further wheel is beveled and the saw is held upon a mandrel on a slide. The usual profiles for these "saw-gummers" are shown by Fig. 333, which also illustrates forms which may be required if the second wheel be intended for the cutters of wood-molding machines. Fig. 334 shows a gummer mounted upon universal joints, by which it can easily be presented to its work.

But in addition to its uses as a tool-sharpener the emery-wheel and grinder may be applied as a shaping-machine for general or for special manufacture. It can only be used with economy upon surfaces which are *nearly* correct, or upon those for which the reciprocating or milling cutter are not applicable. To this class belong the tools for acting on hardened steel, and for shaping and removing the fins from sandy castings. Fig. 335 illustrates a special machine for this latter duty, where beveled surfaces may occur frequently. In place of the conical wheel any other shape may be used, or a pot-wheel may be put on for dressing the inside of hollow ironware. The

table can be tilted for any degree of bevel, and the spindle is carried in boxes upon a guided cross-head, which may be lifted by the hand-lever. By the use of false tops with centers and clamps stove plates may be turned and beveled with great rapidity, and the machine may be applied to a variety of miscellaneous work. Horizontal grinders are also applied very generally for this type of duty.

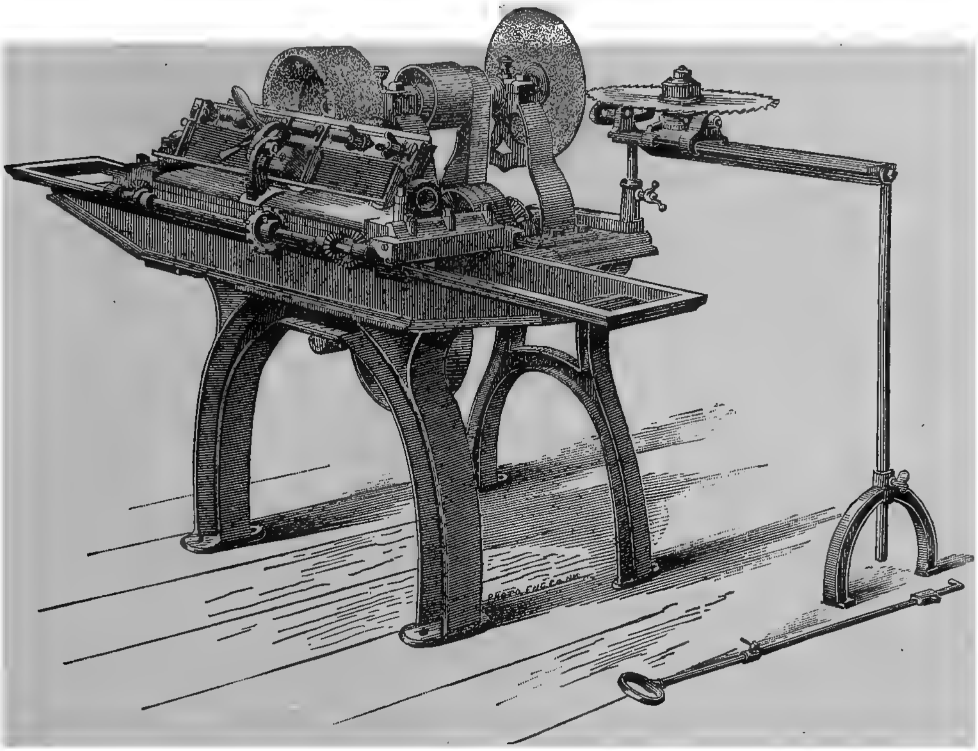


Fig. 332.

For work upon hardened-steel surfaces of revolution the lathe shown by Fig. 120 has been alluded to, with the emery-wheel mounted on the carriage and receiving a traverse motion automatically from the driving-head. A tool of similar principle is also used for grinding into approximate truth the treads of chilled car-wheels. Both wheels may be trued at once as they revolve with their axle held between centers. The emery-wheels are fed by a slide-rest mounting. For grinding taper work, straight or curved, as well as cylindrical pieces for arbors, cutters, etc., the machine of Fig. 336 has been designed. There is a movable table on the top of the primary, which may be swung around its center by a tangent-screw and graduated arc, so that the centers are always truly in line. The longitudinal feed is by rack driven from open and crossed belts, which are clutched to the train by appropriate stops on the table. The clutch cannot stall, because the device of a spring wedge is applied to it. By this machine straight and taper holes may be ground, such as hardened boxes and standard ring gauges. The wheels may be used with or without water, and all the working surfaces and slides are protected. Wheels from one-fourth of an inch to 12 inches in diameter may be used. Graduated arcs assist in setting the work for taper grinding either external or internal.

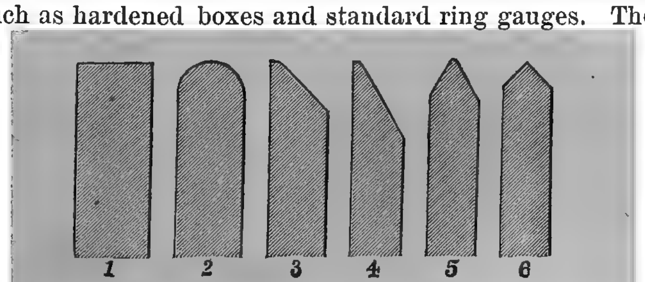


Fig. 333.

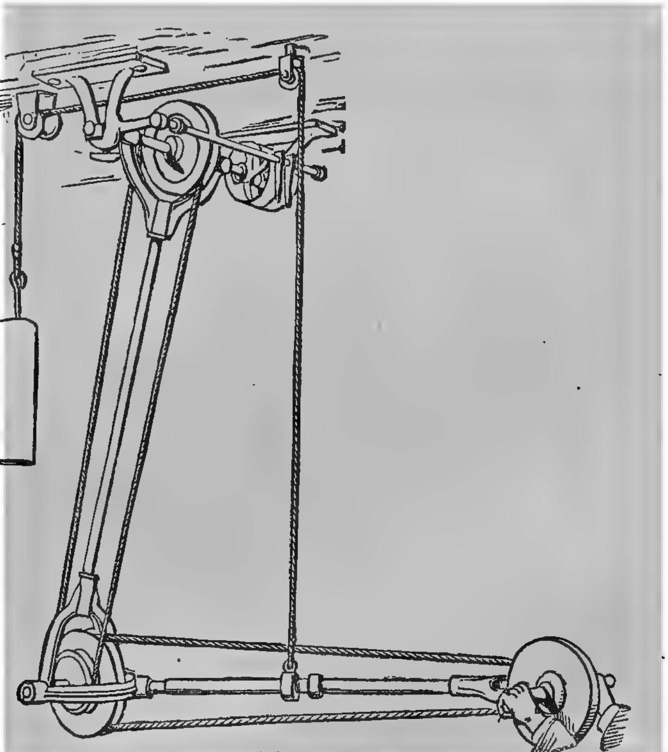


Fig. 334.

Figs. 337 and 338 show similar machines.

For flat and true surface grinding and finishing of hardened or soft work the machine of Fig. 339 has been designed. It is to act as an effective substitute for filing, scraping, and stoning. An emery-wheel is hung from

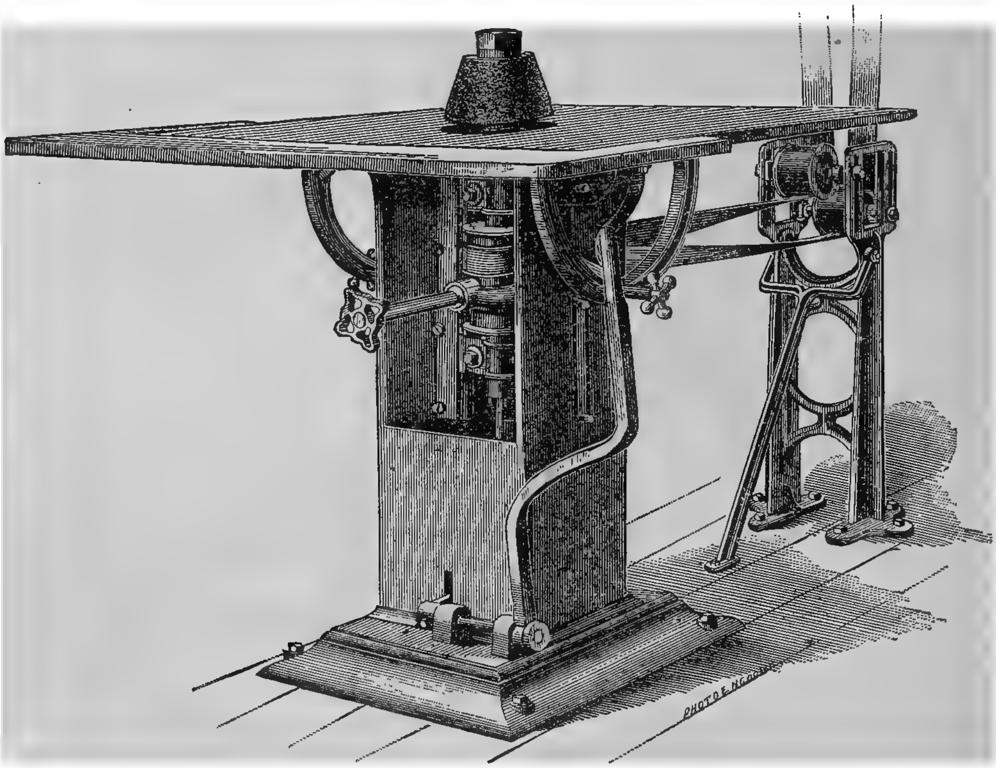


Fig. 335.

the cross-head, and is driven from the long drum at the back. The adjustment of the cross-head takes place around the axis of the drum as a center. The table is fed by a planer-gear with open and crossed belts, and the wheel-saddle receives a feed from a friction device through sector and ratchet. For punches, dies, flattening-dies,

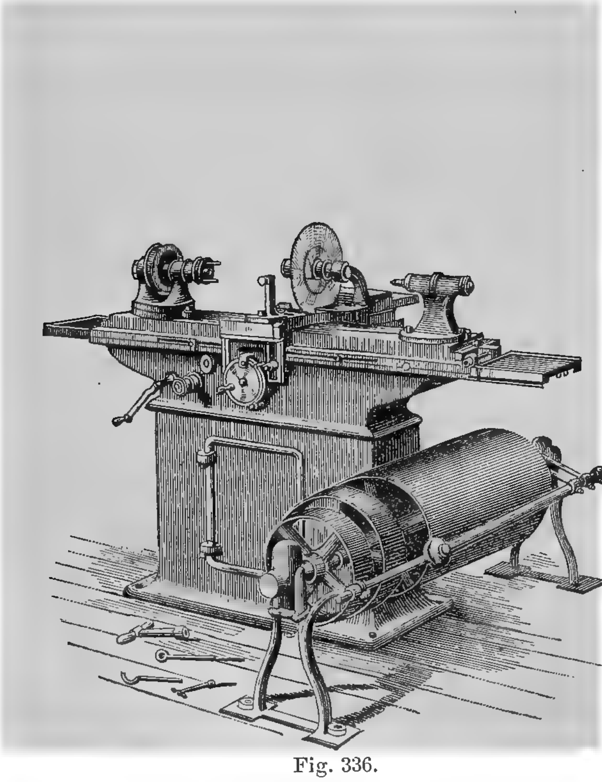


Fig. 336.

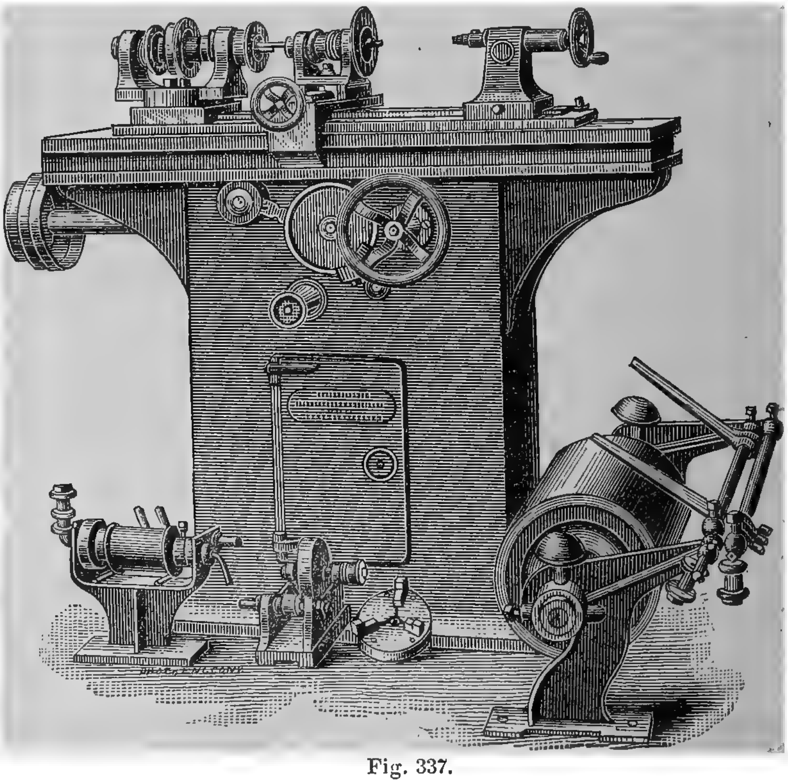


Fig. 337.

straight-edges, and work of that class, this machine is claimed to save three-quarters of the labor usually expended, and to replace the cost of files by that of the more lasting wheel. It is a machine which is a symptom of the demand for a higher grade of workmanship in many branches of shop-work.

For polishing purposes, the solid wheels are not much used, because a polishing-wheel should glaze, while a cutting-wheel should not. A few which can be run with oil may be used for polishing. More usually, however, for

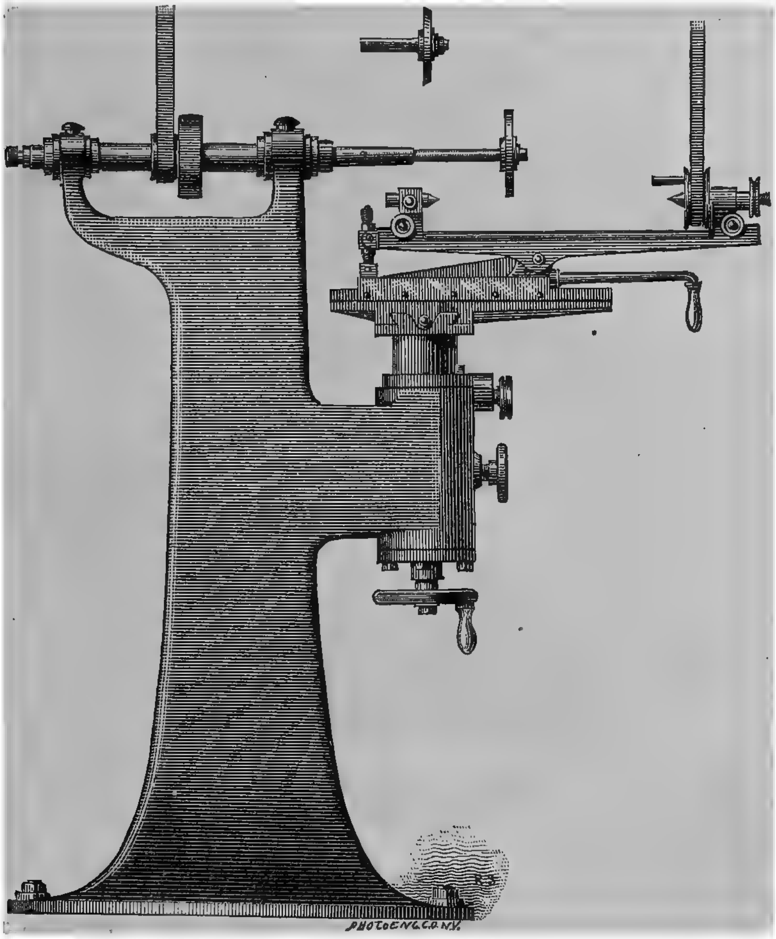


Fig. 338.

this service, as already stated, emery is used upon a leather face glued to a wooden wheel. This wheel is built of overlapping sectors, breaking joints, of selected wood which will not warp. These can scarcely be called emery-wheels, however.

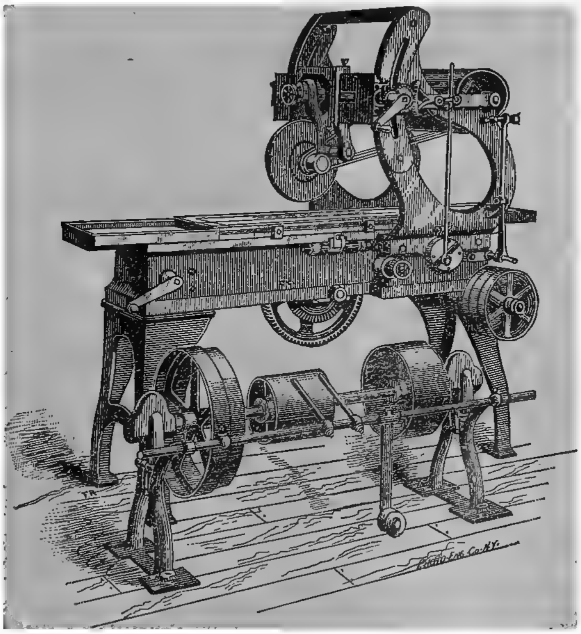


Fig. 339.

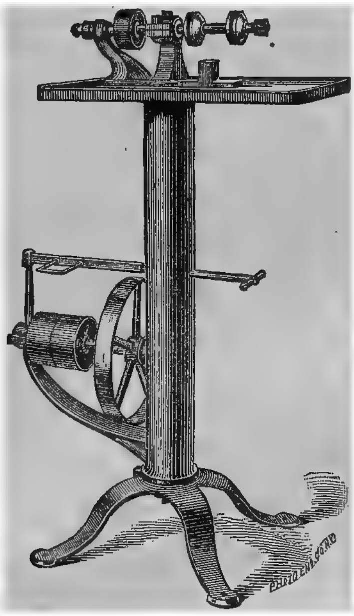


Fig. 340.

For fine buffing a leather-covered wheel is used, upon which the successive grades of emery may be used loose, from the coarsest to the finest required for the finish in question. For the most brilliant luster on brass-work

a felt or cloth wheel is used, often known as a "rag wheel". Disks of the flexible fabric are secured between flanges, and centrifugal force gives them the necessary stiffness when revolved at high speed. Crocus-powder is used for the last polishing with wheels of this class. Their great difficulty is the jarring and chattering, due to lack of proper balance, which is increased by the leverage due to the usual overhang. The journals are apt to give trouble. In the machine of Fig. 340 the long central journal is tapering, and the other is cylindrical, with a tail-screw. By this means any vibration can be taken up. This machine is also adapted for light tool-grinding, with solid wheels. Its avoidance of end-play gives it special advantages for certain classes of such work. Special patterns of simple machinery for grinding hardened-steel rings on their faces are in use. The ring revolves by friction of a pair of cast-iron rings, the pitch lines of the steel and iron rings intersecting each other. The pair of iron rings may be made to compress the steel ring between them with any desired pressure, and the grinding is done with powdered emery and oil.

§ 34.

TOOL-ROOM.

A discussion of the machine-shop tools driven by power would be incomplete without a supplementary allusion to the contents of the tool-room. Every large establishment has a space devoted to the storage and repair of those hand-tools which need not necessarily form a part of the outfit of each operator, but which may be common property, accessible when needed. Every machinist either owns his own hammers, wrenches, scales, callipers, and the special gauges needed for his machine, or else they belong to the shop, which holds him responsible for their safety in his kit. Files and chisels which wear rapidly often come through the supply-room, and are kept separate from the more permanent tools. In some shops these two divisions are combined.

In shops which do any outside repairs or large erecting hand-drills will be required. For very small holes, where but little pressure can be put on the feed, the breast-drill will be of service. For heavier work the ratchet-drill is best (Fig. 341). The conical step at the top abuts against an arm clamped to the work. For very heavy drilling the ratchet-arm may be extended by slipping a piece of pipe on it.

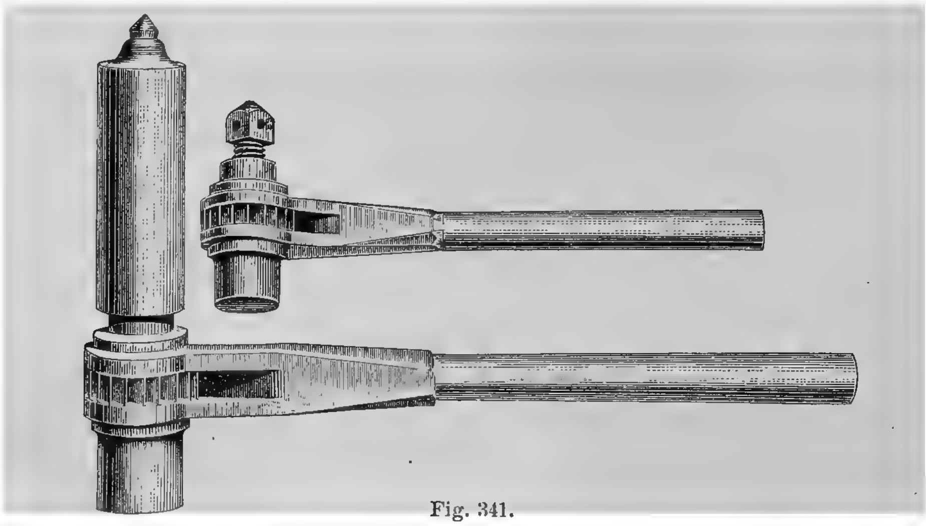
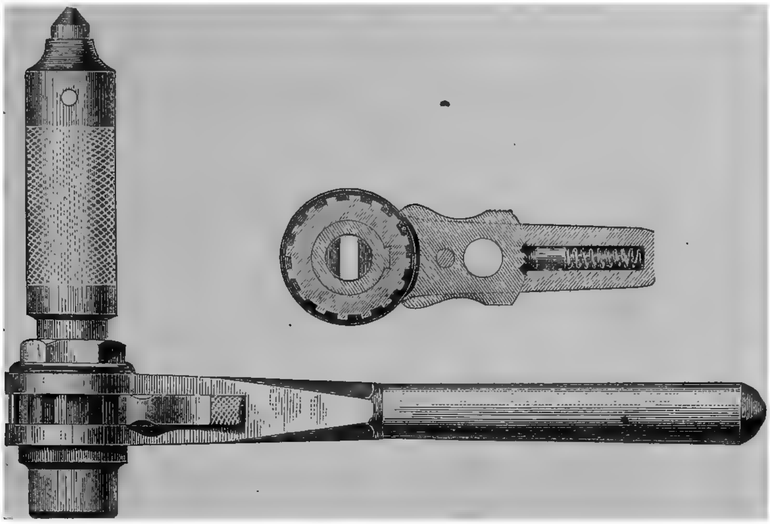


Fig. 341.

Fig. 342 illustrates an improved device by which the pawl on the arm may be either right or left handed, or may be disengaged entirely. The cut also shows how sockets may be introduced to accommodate drills with shanks of different shape.

The tool-room usually contains a full complement of drills of the usual sizes, and often those of unusual sizes. Those in most frequent use are often racked upon the drills themselves, the tool-room having duplicates. These drills consist to-day of a majority of flat or fly drills, which are gradually being displaced by twist-drills (Fig. 343). This displacement is in some shops complete. It will probably be so in all before long. Twist-drills are made with the taper shank as shown, or straight. The taper largely predominates. The newer ones are scribed with a grinding line on the hollows of each side. By working to this always the cutting-point will always be in the axis of the drill, and the hole drilled will be no larger than the drill. The drill-presses are fitted to receive a socket in a taper hole in the end of the spindle. This socket may either be keyed in the spindle by a steel key through a slot in both (Fig. 344) or the fit may be by friction. Sockets of different sizes will be used for larger or smaller drills. Those not in use will be in the tool-room, as well as special sockets for odd sizes. The milled tail of the shank prevents the butt of the drill from getting marred, so as to spoil the fit in the socket, and also permits of light keying in the slot. If pin-drills are called for by the requirements of the shop service, they will be kept here. They will be used for boring out a large hole, for which a small hole has been made in the axis as a guide.

For accurate cylindrical holes the simple drill will not answer. It will not necessarily produce a hole either straight or round. It is necessary, therefore, to bore the hole a little small with the drill and bring it to standard size by a reamer. The solid reamer (Fig. 345) enters the hole by a short taper, and enlarges it to the size desired. For very rapid work, as in bridge-plate, and especially for punched steel plate, the self-feeding reamer is approved. The short thread carries the tool rapidly forward (Fig. 346). For certain metals the reverse of this is desirable,



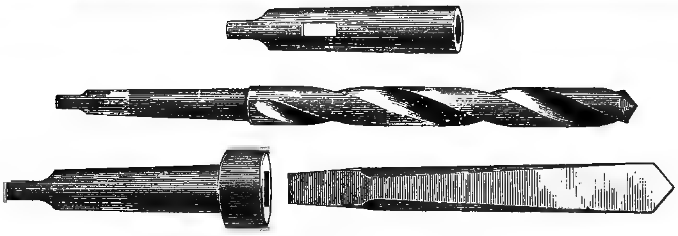


Fig. 342.

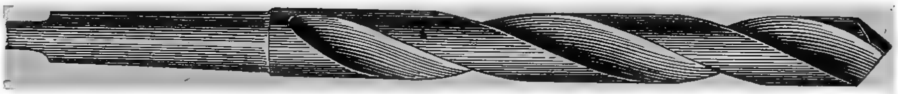


Fig. 343.

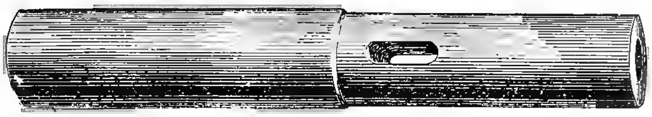


Fig. 344.

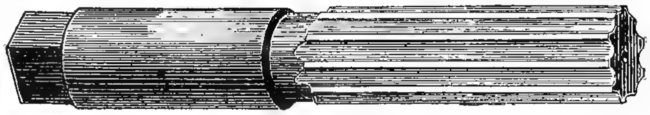


Fig. 345.

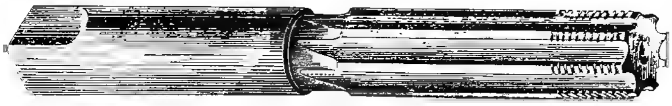


Fig. 346.

Fig. 347.

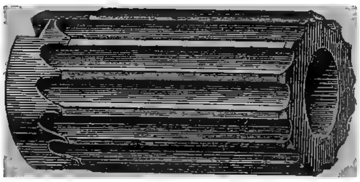


Fig. 348.

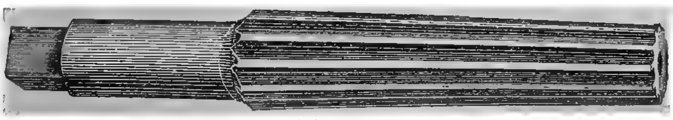


Fig. 349.

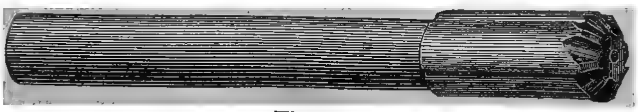


Fig. 350.

and even the plain reamer may feed itself too rapidly. To meet this case the relief reamer has the flutes inclined backward, so that a dragging cut is produced (Fig. 347). The shell reamer works upon a central guiding-spindle (Fig. 348), and the taper reamer (Fig. 349) acts simply to enlarge a hole without exact regard to its truth. The rose reamer (Fig. 350) is usually arranged to be chucked in a taper socket, for producing countersinks and similar duty.

After the production of the holes will be the cutting of screw-threads upon them if they require it. Fig. 351 illustrates the usual forms of taps for bolt- and nut-work. Fig. 352 is the long tap for threading the two surfaces of stayed work so that the screws may fit both.

Fig. 353 illustrates the usual form of pipe-tap, with the standard threads for gas and steam fitting. Fig. 354 illustrates a larger size, with inserted cutters in grooves in the body of the tap.

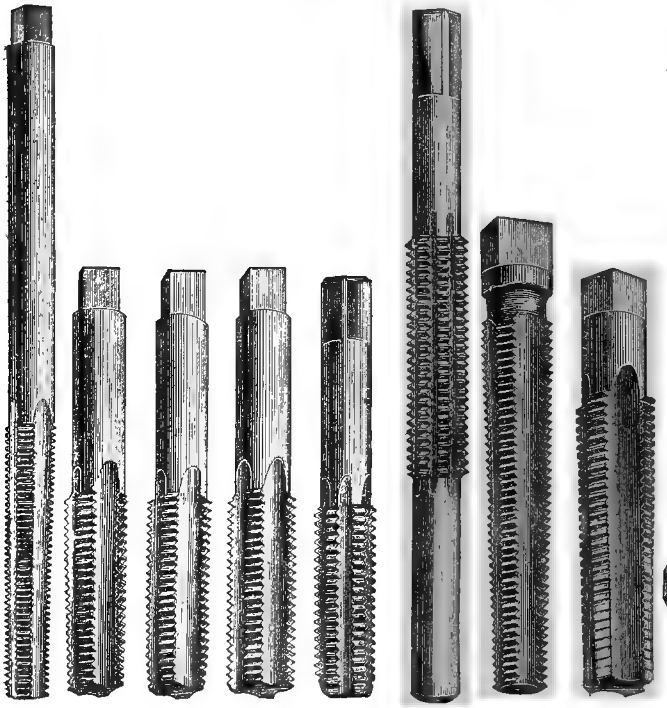


Fig. 351.

Fig. 352.

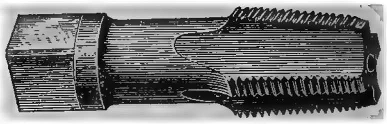


Fig. 353.

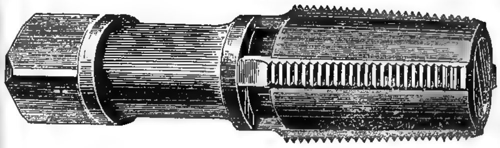
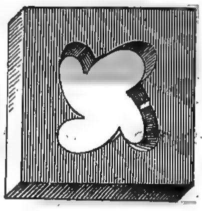


Fig. 354.



For turning these taps a special form of two-handed wrench is used. Fig. 355 shows one form, where the two halves of the square are closed by screwing in one handle. In the other form (Fig. 356) the two halves are brought together by a milled scroll disk and held by a latch.

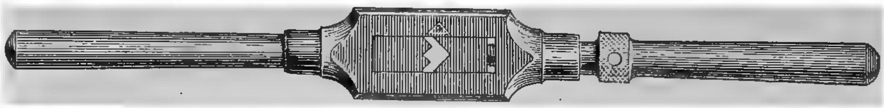


Fig. 355.

For cutting the threads upon bolts and studs by hand a stock with open dies is mostly used. The dies are either milled to fit tenons in the sides of the opening of the stock, with a blank distance-key in the bottom, so that the dies may be changed, or some improved device is used.

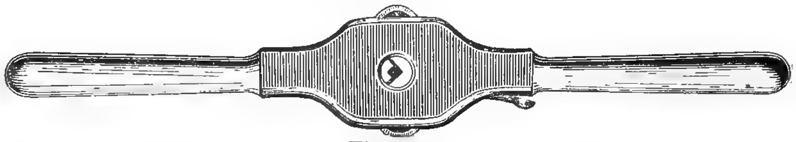


Fig. 356.

Fig. 357 illustrates a convenient one, in which the dies are held by the long arms of the bent levers, which are tightened in sidewise by the pressure of the adjusting binding-screw. When this latter is released, pressure on the stud releases the dies. So simple an arrangement is this that it may be wise to use the stock as a tap-wrench by replacing the dies by blanks.

Figs. 358 and 359 show details of stocks and solid adjustable dies which cut a thread with one going over. The details for taking up wear will be visible from the cuts. For pipe-dies solid dies are most usual of the form shown by Fig. 354. These are held in a stock of the shape of Fig. 361, which has a leader-screw for securing the

proper starting of a large thread. This will be used only for sizes over one inch. Bushings serve to guide the die straight. For small work not infrequently the combined stock is used (Fig. 362), the dies being laid in and covered with the cap-plate as in the larger sizes. Above 3-inch pipe the stock must have sockets for removable arms, because otherwise the vises would not be high enough to let the longer arms clear the floor. There are usually

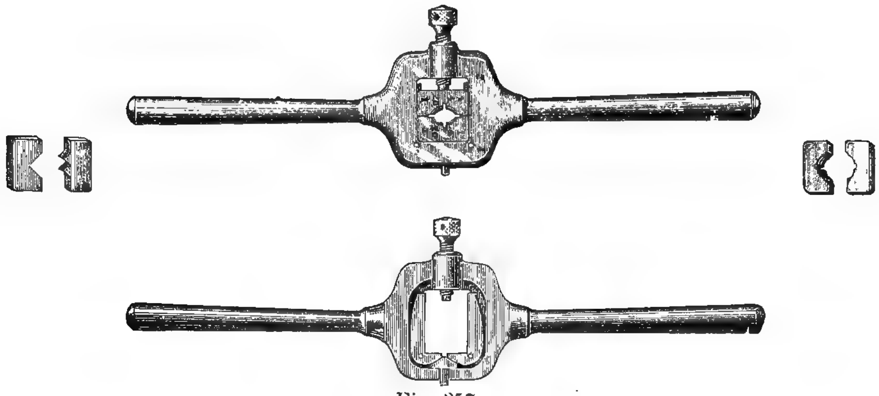


Fig. 357.

sockets for four arms. A great deal of shop-work on pipes is now done by machine. Su an outfit will be for job-work only. Cutters and tongs for the different sizes complete the set. Fig. 363 illustrates an open-die-stock. The compression and adjustment is effected by the screw, which is capped over by the hollow handle.

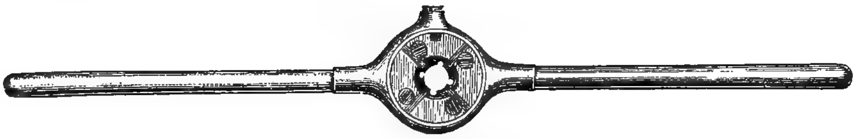


Fig. 358.

It has long been recognized as a corollary to the system of the division of labor that greater accuracy of calibration is necessary than the ordinary scales and calipers will admit. When a number of different men are working at different parts of a job which is finally to be assembled it is only possible to economize time in the

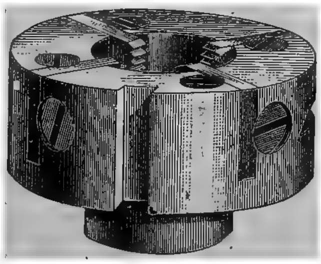


Fig. 359.

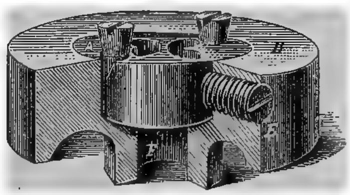


Fig. 360.

fitting operations by securing very great accuracy of dimension. To secure this end many of our best establishments have in their tool-rooms a set of standard gauges, external and internal (Figs. 364, 365, and 367), which are of hardened steel, and are used to set the common calipers, instead of graduated scales. Were they used as

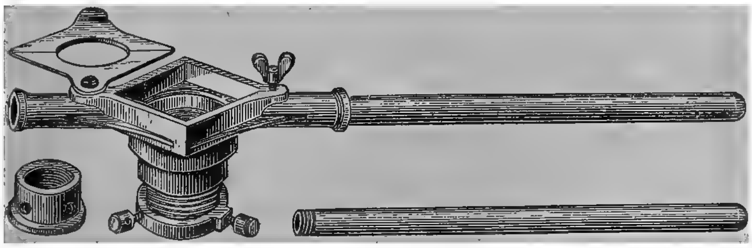


Fig. 361.

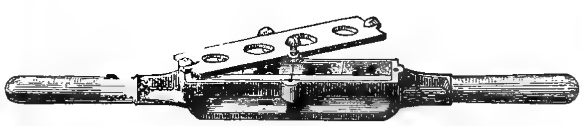


Fig. 362.

gauges in the shop, the wear on the hardened steel would be enough to destroy their accuracy. They may be used to test a set of shop standards, which may be thrown away as they lose their truth. For general shop use several of the exact-tool makers are making the type of gauge shown by Fig. 366 for external and internal calibration. They may be of steel, or one builder is using wrought iron, case-hardened, as preferable. The form of screw-thread

gauge is shown by Fig. 365. For fine calibration and adjustment of special tools a tool-room often requires vernier calipers. Figs. 368 and 369 illustrate two forms of differing capacities. These will both read by the vernier down

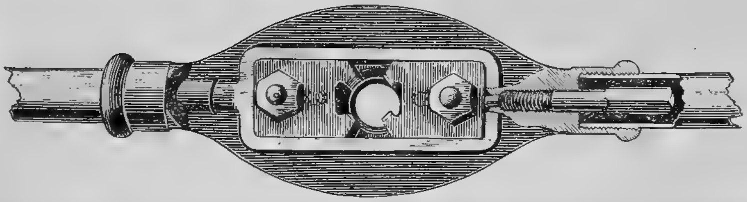


Fig. 363.

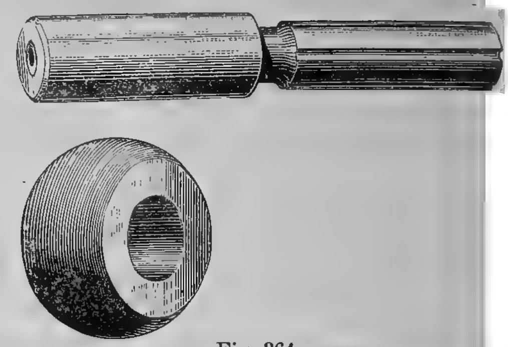


Fig. 364.

to one-thousandth of an inch. The smaller one has an adjustment to secure accuracy after wear. These are not in general shop use as yet for larger types of work. Special gauges, scales, straight-edges, surface-plates, angles, rules, and standards may be called for over and above these for special branches of manufacture. A very few of the shops are provided with an especial machine for exact measurement. By micrometric devices these will read to a high limit of exactness. It is not within the scope of this discussion to describe them more fully.

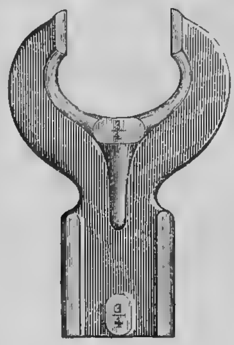


Fig. 366.

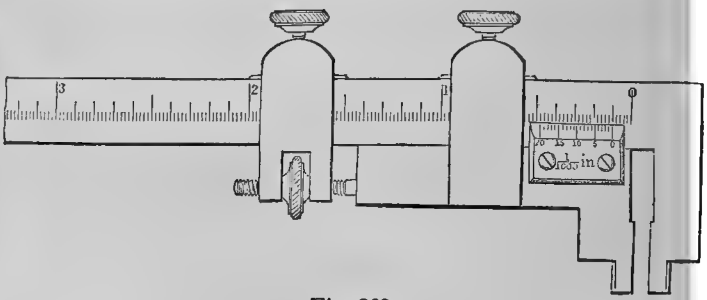


Fig. 368.

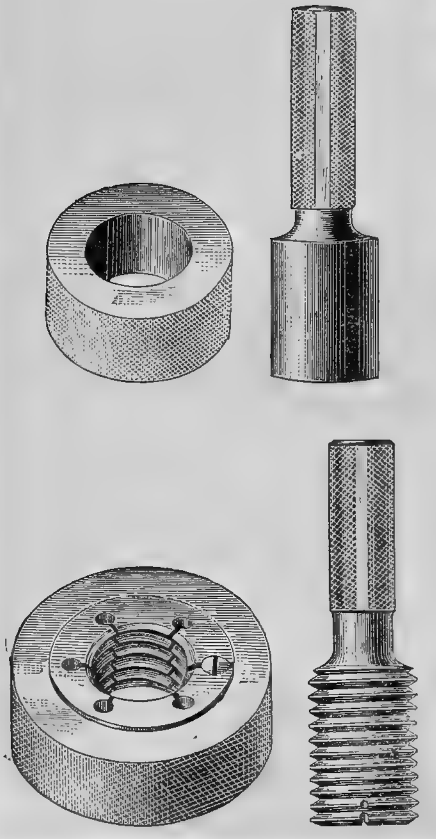


Fig. 365.

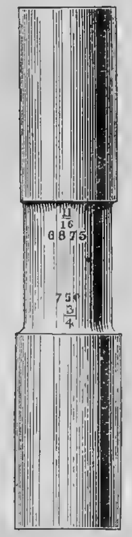


Fig. 367.

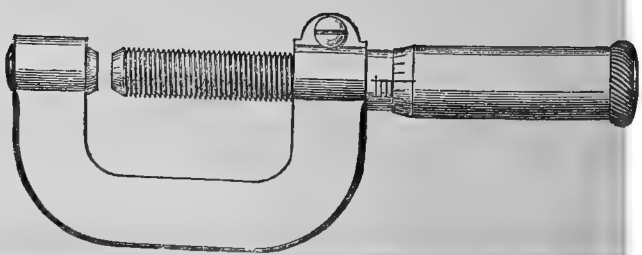


Fig. 369.

Where milling-cutters are used in any variety the tool-room furnishes them and usually keeps them in order also. For all the work on tools in the tool-room, both general and special, the machine-tools characterized by their universality and exactness are best adapted. It is for such uses that the milling-machine and the emery grinders are very frequently applied.

§ 35.

It has not been thought necessary to enter largely into the subject of the linear capacity of the tools discussed. Such information is easily accessible to those who wish it. Neither has special commendation been awarded. Those who are expert in such matters will detect from the descriptions those features which deserve it. But it may not be amiss to call attention to two points which have had a great influence in raising the standard of machine-tool manufacture in this country. The first is the increasing respect for the small decimal subdivisions of the inch and a more complete understanding of their significance. This is manifested in the prevalence of the use of exact standard gauges, and by the increased strength and stiffness of the designs of the newer tools. It is understood that properly distributed weight of metal is necessary and desirable, and a heavy tool will do light work far more accurately than a light one can do heavy work. By proper resistance to the strains of the cut the tool is *expected* to do exact work, and its designer and its maker do not and should not rest till it accomplishes that end. The second point is the increasing prevalence of hand-scraped surfaces, tooled with a hook-scraper and worked up to true planes. The use of the file and emery-cloth to produce a finish pleasing to the eye only, while the surface was mechanically untrue, is a thing of the past in our best shops. By this advance every bearing surface bears all over, and not at a few points only. Wear is diminished, and the motions take place in true straight lines.

A third point might be the extended use of hardened steel, ground and lapped. The truth of the fit originally made by the maker remains for a long time to benefit the user.

It is for these reasons, and for others which might be adduced, coupled with the mechanical genius of their designers, that American machine-tools have reached the degree of excellence which characterizes the best of them.

Part II.—WOOD-WORKING MACHINERY.

§ 36.

It is proposed to discuss the class of wood-working machinery between the limits which are parallel to those established for the machine-tools. The forest-sawing of the lumber will be considered as preliminary to the tools in question. This is the limit parallel to the metallurgical tools and processes for the metals. It is equally out of the aim of this section to enter on the subject of the special tools which have an important bearing in one or two lines only of special manufacture, such as chair, barrel, sash and blind, wheel machinery, and the like. This limit corresponds to the further limit of the previous discussion. Between these two limits lies a large class of those general tools which are of universal or extended application in house- and car-building and in the pattern- and carpenter-shops of engineering establishments. These are of primary importance, and will be brought under notice.

The differences between the metals and the woods give rise to very marked differences in the structure and in the action of the tools for the two classes of material. On account of the softness of the woods relative to the cutting-edges, wood-workers permit and demand that the conversion into the required shape should be rapid. Revolving cutters will therefore predominate, and they will be driven at the highest speeds. The high speed is also necessary on account of the fibrous character of the woods. At slow speeds, the surface would be more likely to be torn than to be cut by the shaping-edges. It is the existence of the fiber or grain of the woods which gives rise to the different methods by which wood-working tools operate. These are:

F.—By scission.

G.—By paring.

H.—By combinations of these two.

I.—By abrading.

The tools acting by scission are those which act to sever the fibers of the woods across the grain. This class includes the numerous varieties of saws. They might also be called tools acting by disintegration, since they penetrate and shape by reducing the material in their path to a fine dust. The second class, which acts by paring, would include those which produce shavings or chips by acting upon the fibers in the direction of their length. Such would be the surfacers, planers, matchers, friezers, and molders. The tools of the third class would be those which act upon the fibers both lengthwise and crosswise. They must therefore partake of the capacities of both the others. Such are the lathes, boring-machines, the mortisers, rotary and reciprocating, and the gaining-machines. In these tools there must be a spur or saw-segment to sever the fibers before the chisel-edge can pare away neatly the material to be removed. The class of machines acting by abrasion or grinding includes the sand-paperers and the like. These, however, are rather for ornamenting or finishing the work of other tools, and are therefore secondary. It is the saw and the chisel of the handicraftsman which furnish the basis of all the wood-working machinery. The plane, the gouge, and the bit are themselves deductions from the primary two. The sand-paper and the file are the originals of the abrading-machines.

§ 37

F.—SAWS.

RESAWING-MACHINES.

There are several reasons why the forest-sawing of lumber to small dimensions is impolitic. It is best to make the logs up into squared stock only, and thus to transport them to the purchaser. Among these reasons are that the thin green lumber will warp and dampness and sun will check the ends. There will be great loss of lumber from the wide kerfs of the log-saws, and the grit, which will adhere to the great surface exposed, will induce the surfacers to take a heavy chip to get under the grit, so as to avoid ruining their knives. For these reasons, and for others connected with the storage of the lumber in yards, machinery for resawing squared stock, either seasoned or kiln-dried, has become of increasing importance as lumber becomes more valuable.

Resawing machinery is of three classes. The first includes the vertical reciprocating saws, the second includes the circular resaws, and the third embraces the band resaws. There are certain features which are, or should be, common to all. The planks are presented vertically to the saws by the means of four vertical rolls, which are driven by power. These may be arranged to center equally upon the saw, so that it shall bisect any plank

presented to it, or one pair may be clamped at one side, so as to act as a guide to insure that equal thicknesses shall be cut for every board. In this case the other pair yields slightly, to compensate for varying thicknesses of the rough stock. For bevel-siding, for clap-boards and similar work, the whole roll-mounting may be swung so as to present the lumber obliquely to the plane of the saw. Their other functions must not be interfered with in this case. Several special features will be alluded to in the sequel.

Fig. 370 illustrates a simple open type of vertical resaw. The saw is strained in a sash or gate of wood, driven by two pitmen from the balance-wheels overhead. Wood is used for the sake of lightness. The feed is given by

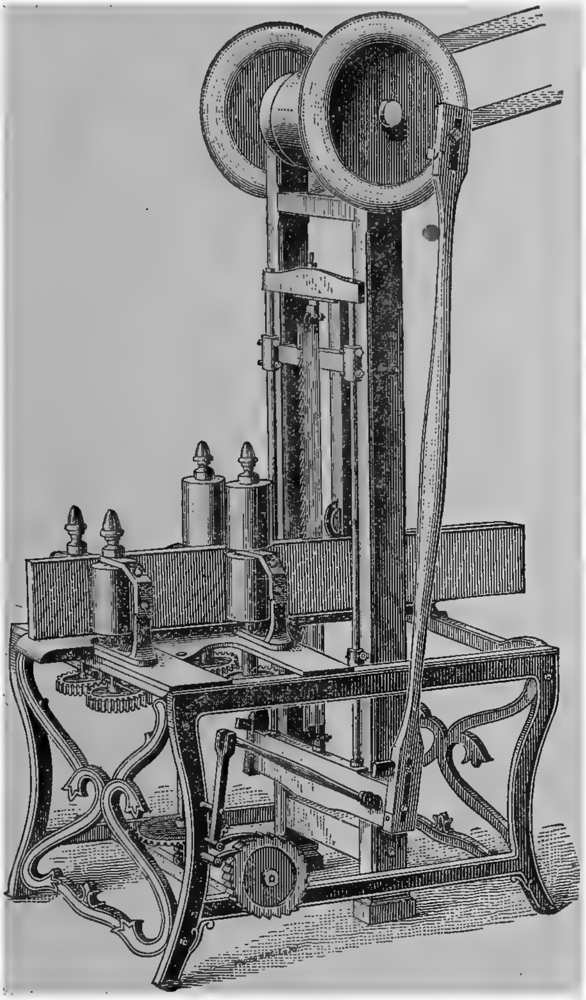


Fig. 370.

lever and dog from the gate to the gears on the roll-spindles. The stock is kept from rising by an adjustable roller, which carries a flange, and acts to wedge open the cut. The rolls have their secondary bearings adjustable. The intermittence of the feed relieves the saw in part on the up-stroke.

Fig. 371 shows a larger and heavier type, with the balance-wheels below. The pitmen have adjustable stub-ends, to take up wear and to insure equality of length. The rolls are driven from a separate belt-wheel, and are adjusted laterally by the levers and links from in front. A spiral spring controls the feeding pressure, and the feed is continuous. An adjustable weighted device keeps the plank from rising with the lift of the saw, which tendency is increased by the continuous feed. A still larger type is shown by Fig. 372, where the gate is of iron and the pit below accommodates the pitmen and wrist-plates. The gang-saw, with several plates in one gate, does not seem to have been generally applied for fine resawing. It has been approved for heavier work more extensively.

The strained vertical saw has the advantage of economy of kerf. A very thin blade may be used, and made wedge-shaped in section. To be opposed to this is the slow speed of feed—from 4 to 6 feet per minute, according to the width of the board. This is due to the necessarily slow speed of reciprocation, and to the fact that the saw is cutting during only one-half of the time.

The circular resaw is in most general use at this date. It has the advantage of continuous cutting action and high cutting speed. Its disadvantage is the wide kerf which must be cut. The saw-plate must be thick enough

to retain its stiffness when at work and under the action of centrifugal forces, and to attain this, greater thickness is demanded than in strained saws. Various devices to secure stiffness with small kerf-losses are exhibited in the various designs.

To compensate for the wear of the saw most of the designs have the mandrel-boxes adjustable, so that the saw may be kept close to the guiding-rolls. A smaller saw can also be thus admitted. The front rolls must be very close to the saw, inasmuch as the top part only cuts when the stock is over the mandrel. The front rolls are often made longer than the back ones.

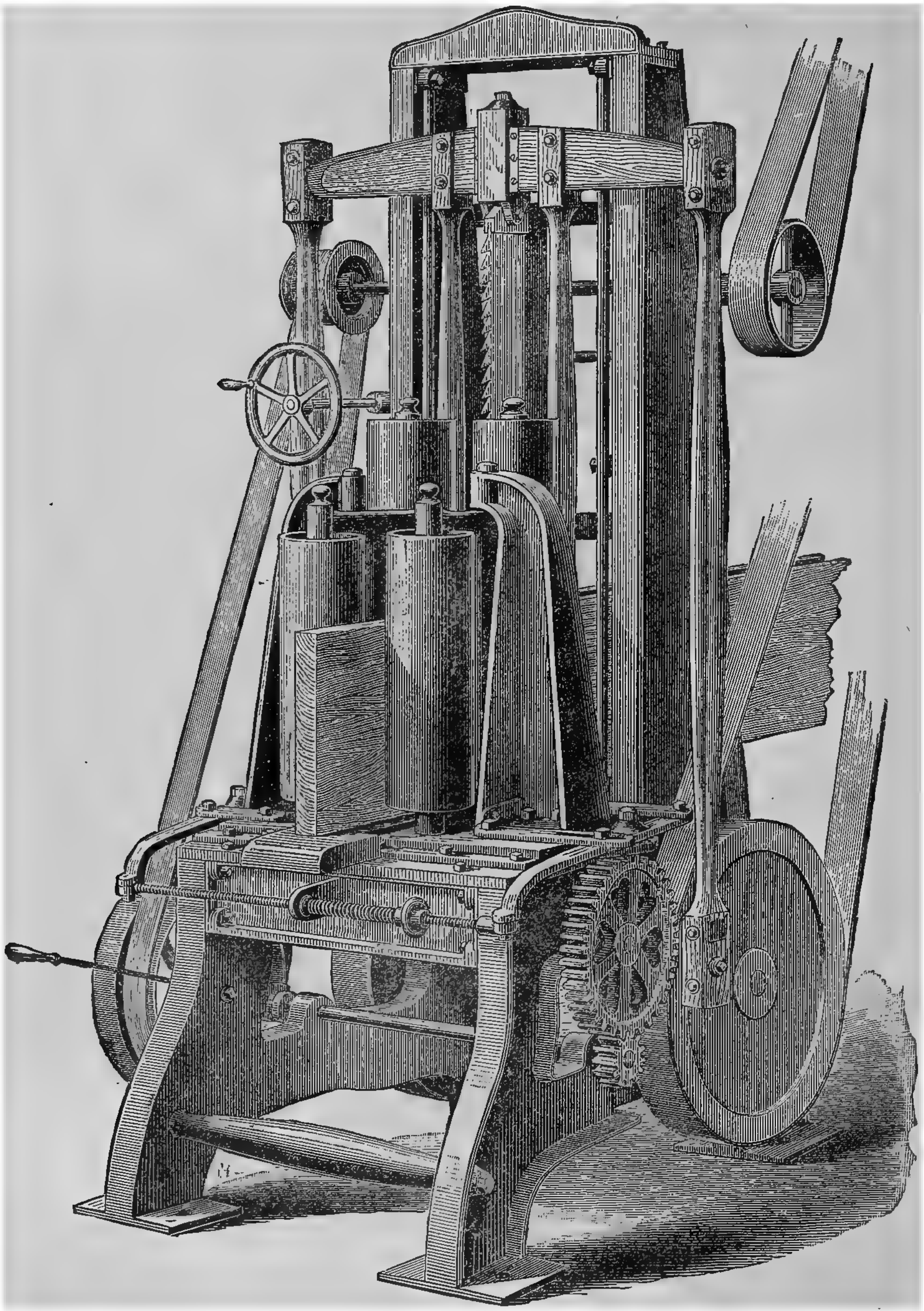


Fig. 371.

Fig. 373 shows a thin saw stiffened by a flange, to which the blade is screwed. The other side is flat, working against the stiff stock, while the flexible board is wedged away so as to prevent the plate from heating. The feed is given by reducing-gear from the arbor, but is still at high speed. The pairs are connected together by gearing on top, and receive their motion from the bevel-gears on the splined shaft below. The gears slip on the shaft laterally to permit the adjustment for varying thickness of stock. The bent lever and weight act upon a double wrist-plate to center the rolls upon the saw. The rolls are supported in long bearings in saddles upon a slide below. This is a very usual arrangement. The slide casting may rock upon a central pin for bevel-sawing. It is adjusted by a screw, and further clamped by the hand-nuts in the slots of the arc.

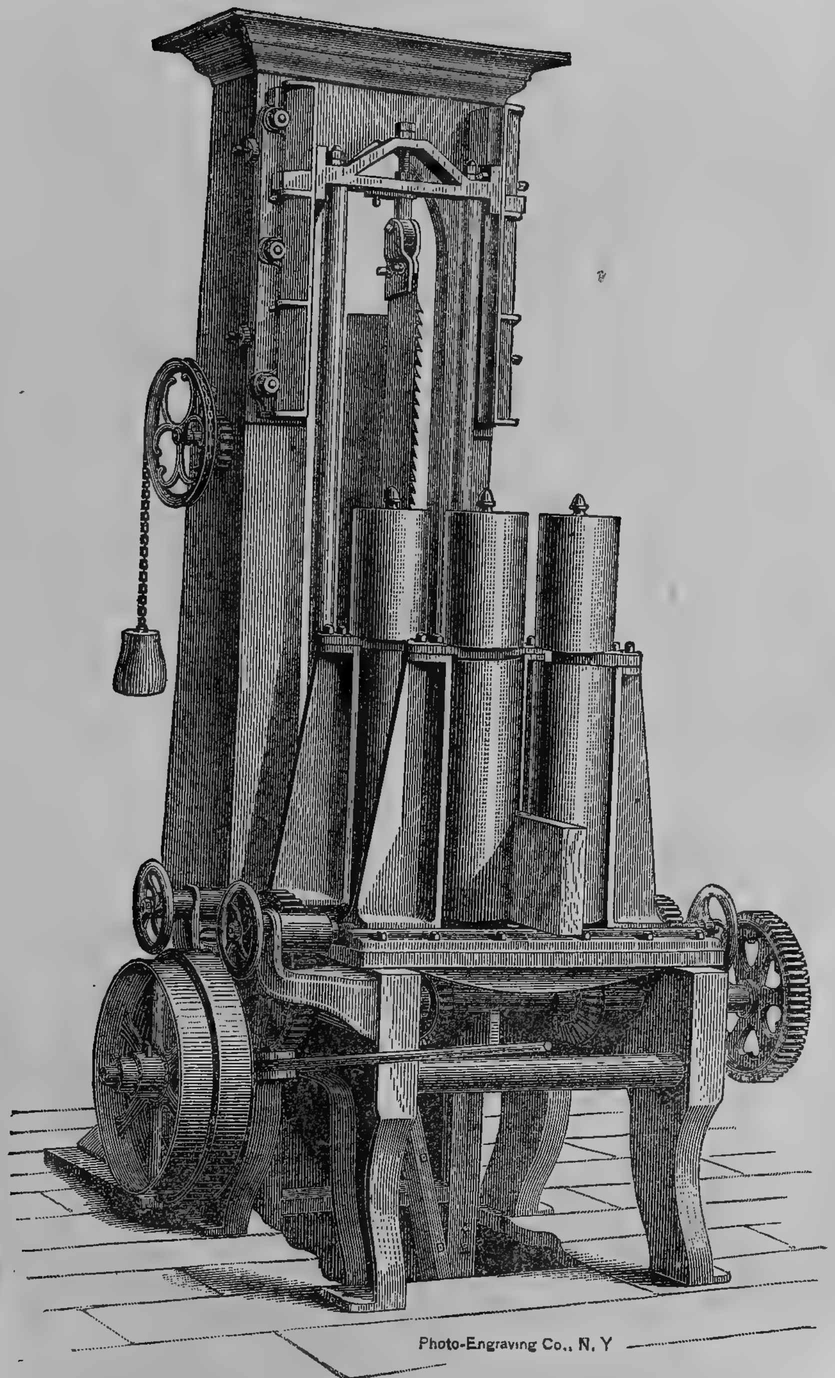


Fig. 372.

Fig. 374 shows a machine with taper-ground flanges on the saw, permitting the use of thin saws. A pair of friction-rolls project well over the plate to guide wide stuff near the cut. The weighted lever acts by equalization,

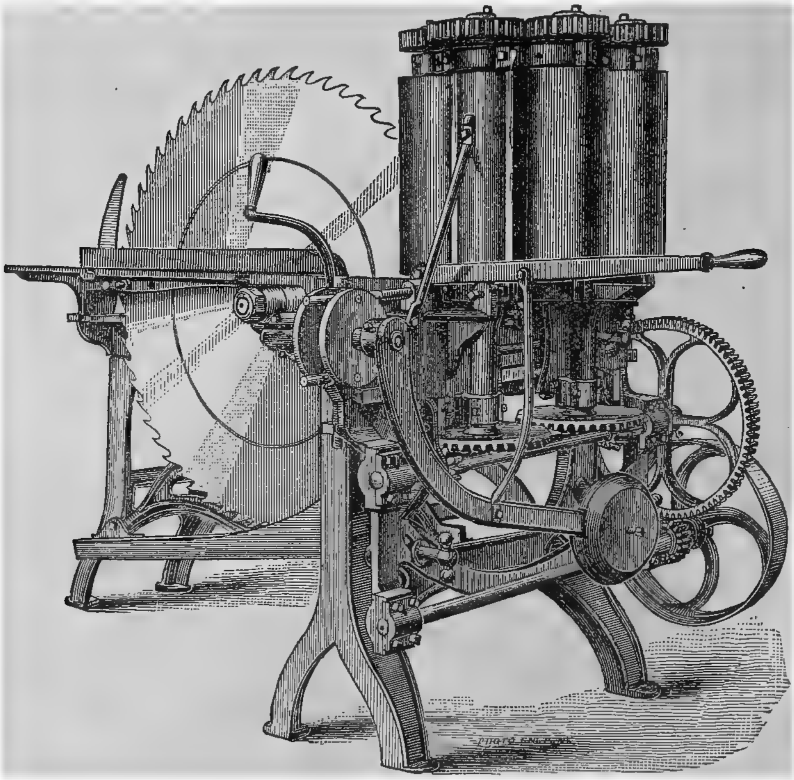


Fig. 373.

so that either center or side cuts may be made. The whole feed apparatus will swing for bevel-sawing, and the feed may be arrested by a clutch at the right. Dust is caught in a trough, which also shields the bottom of the saw.

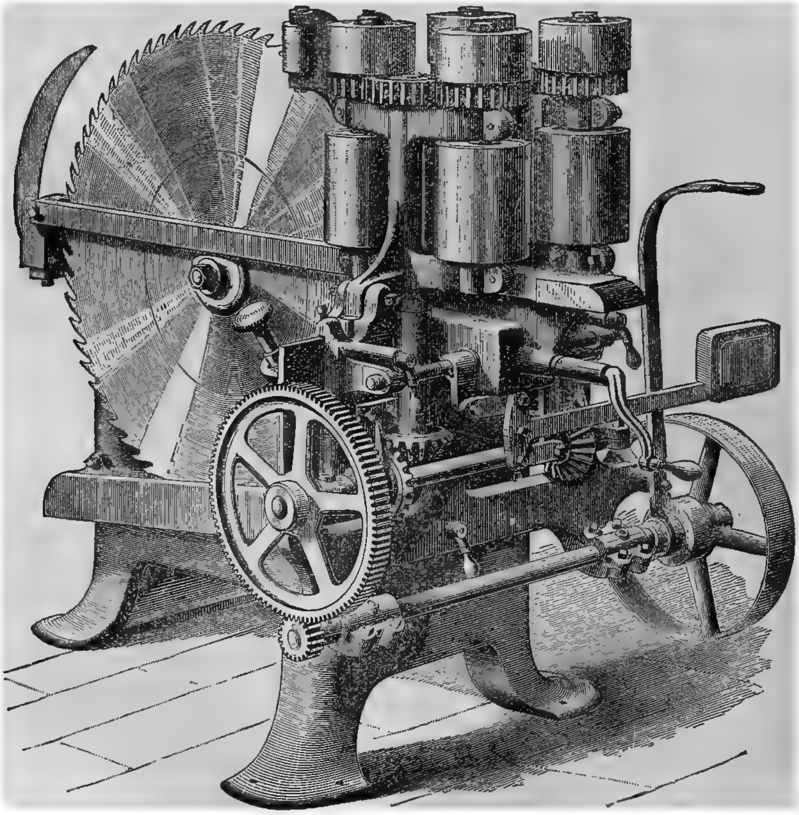


Fig. 374.

Fig. 375 shows a saw with inserted teeth. By the incidental use of softer plate this system also gives a thin kerf of less than one-eighth of an inch with a 50-inch saw. The rolls are mounted on separate slides, which are

inclined so as to be normal to the resultant of the weight of rolls and stock and to the push against the latter, due to the cut. The rolls are steadied by adjustable ring-bearings, by which inclination of their axes is permitted. There are three changes of feeding speed and a disengaging-clutch. All adjustment of the rolls, from center to side cutting, is effected from the feeding end by hand-wheel.

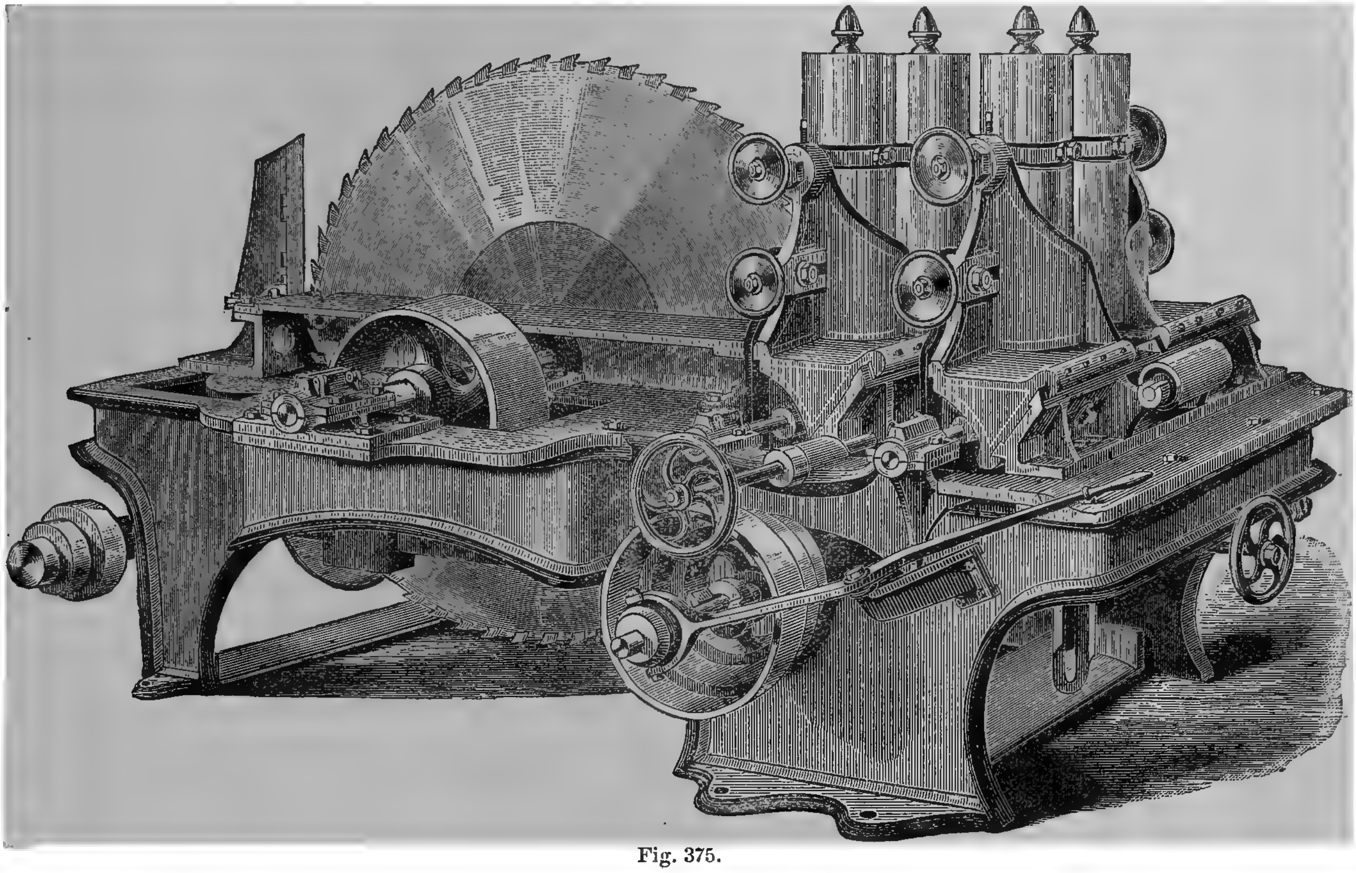


Fig. 375.

Fig. 376 illustrates a type which has some special features. The saw is guided by end-wood adjustable guides at both ends of the horizontal diameter and at the top. By this principle of guiding a great reduction is possible

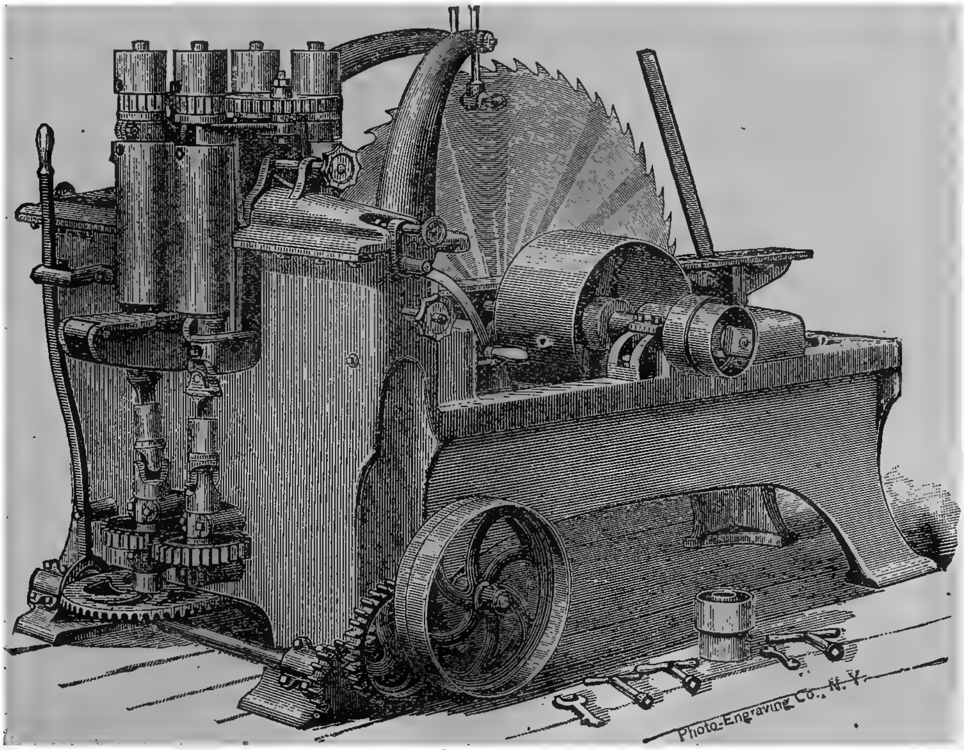


Fig. 376.

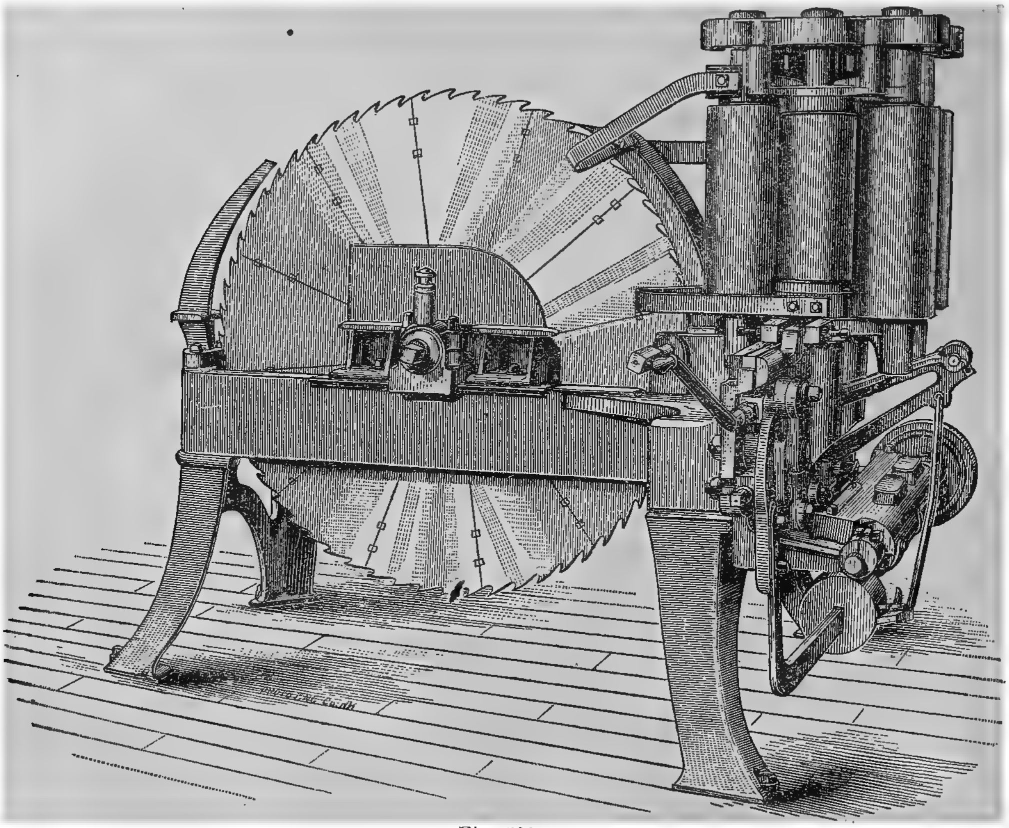


Fig. 377.

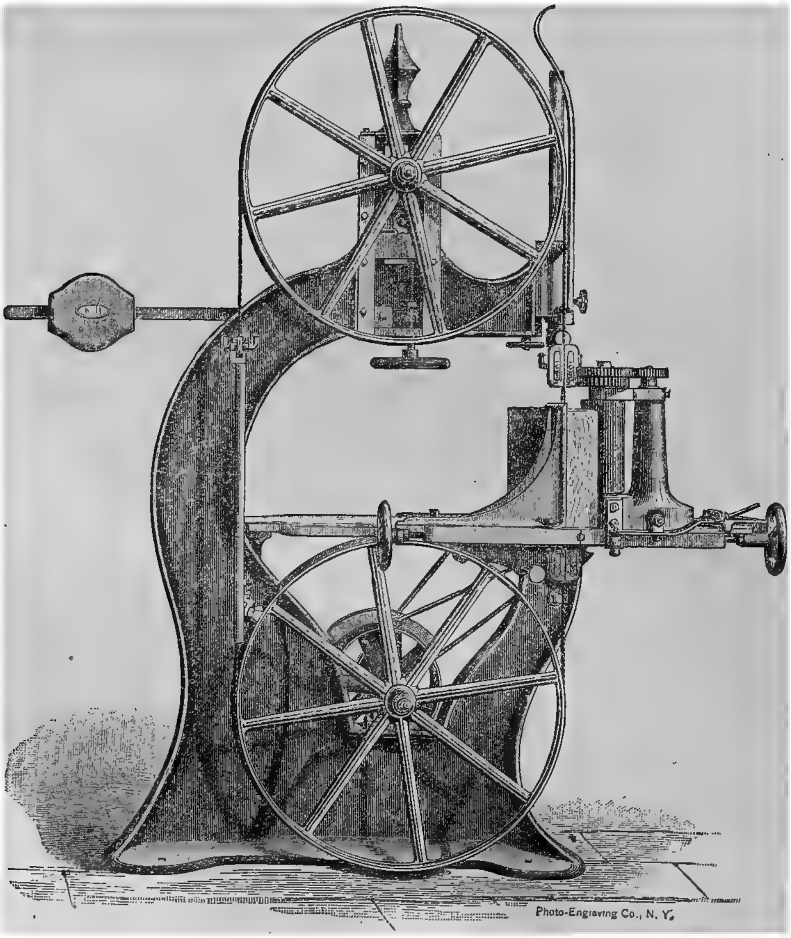


Fig. 378.

in the gauge of the saw-plate, and hence in the width of the kerf. The circular saw at high speeds yields very easily to lateral pressure, and will not cut to true lines when thin unless guided near the cut. Moreover, the guides upon which the rolls yield are placed near their middle points. By this means the pressure upon the stock does not cause a binding upon the slides and guides, which will be caused when the slides are vertical and below the working level. The rolls can easily be set to any required bevel. Instead of being driven from a splined shaft with sliding bevel-gears, the pairs of rolls are driven from fixed spur-gears by universal joints and telescopic shafts. This avoids the wear on the splined shaft due to the leverage which the rolls exert. There are two changes of feed which may be disengaged by the lever at the left if necessary to withdraw the stock for any cause. The arbors are made hollow, to prevent springing.

Fig. 377 shows a segment-saw. The segments are connected together by copper dovetails. While the gauge at the circumference is 16, at the center it is 5. The feed is given to the rolls from a long gun-metal worm, which is driven by round belt from the arbor. The worm-wheels will roll upon the screw for any adjustment laterally, and

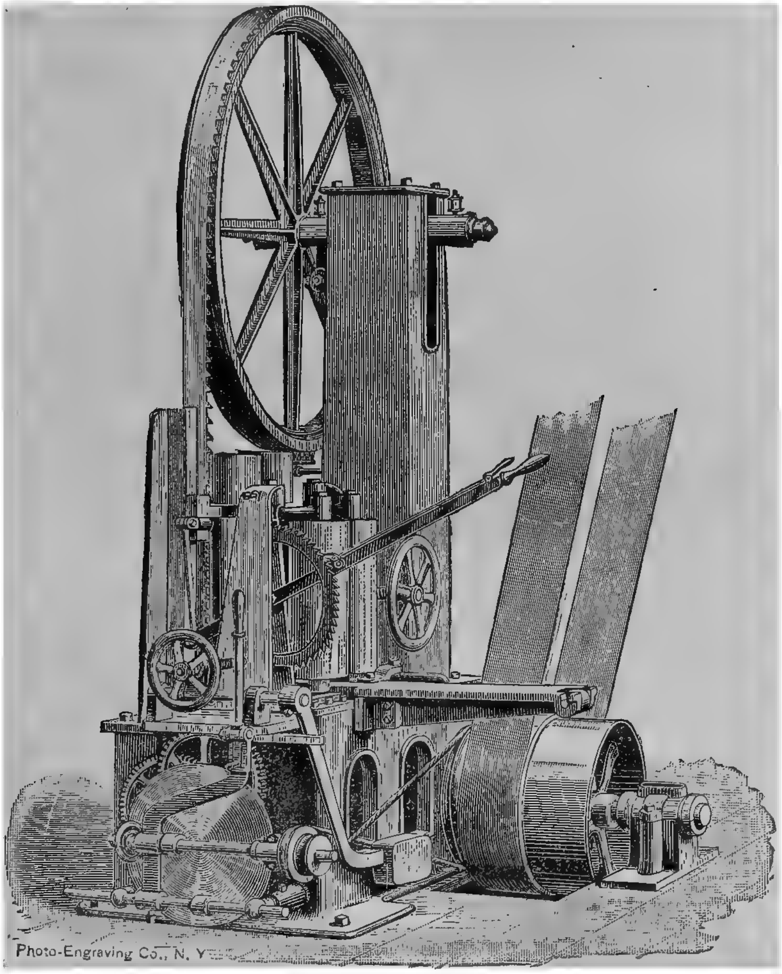


Fig. 379 *a*.

the whole feed works will swivel for bevel sawing. The weighted lever bears upon an equalizer, and the rolls are geared together at the top. The use of the worm simplifies the feed-gear very satisfactorily. Other builders use the segmental saw for their larger sizes, or when preferred by their customers. By the use of the circular saw the feeding speed may vary from 25 or 30 feet to the minute up to 90 feet on narrow lumber. Forty feet per minute would be perhaps an average. A notable economy results from this increase of velocity.

The manifest advantages of the band-saw for other classes of sawing has led some of our advanced builders to adapt it for resawing. These advantages are its great thinness, its variable tension, its linear and continuous motion at the cutting-point, its high speed, the simplicity and rotary motion of its machinery, the easy delivery of dust, the coolness of the blade, and its taper- or wedge-shape.

Fig. 378 shows one of the lighter types of the band resaw. The lumber is pressed against a guide-plate and driven by fluted rolls. For the feed-gear of these resaws the brush-wheel combination is nearly universal. It permits any variation of speed of feed, and reversal is possible. The saw has all the usual attachments of belt-shifter and brake, brush to dust the lower wheel, roller-guide for the passage of the blade to the upper wheel,

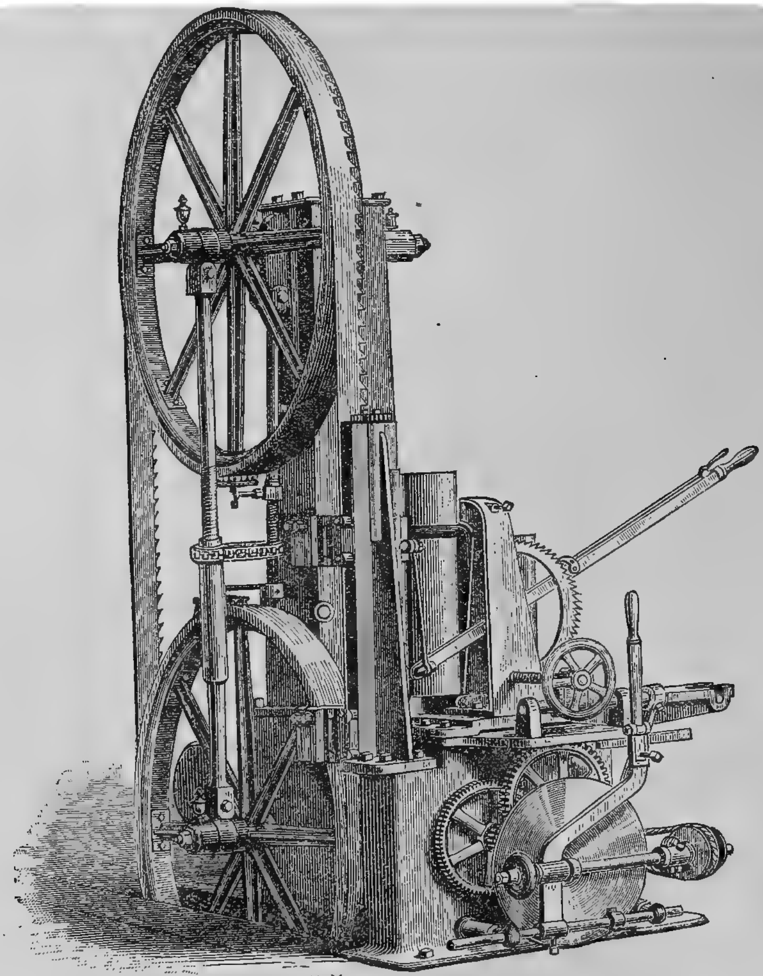


Photo-Engraving Co., N. Y.

Fig. 379 *b*.

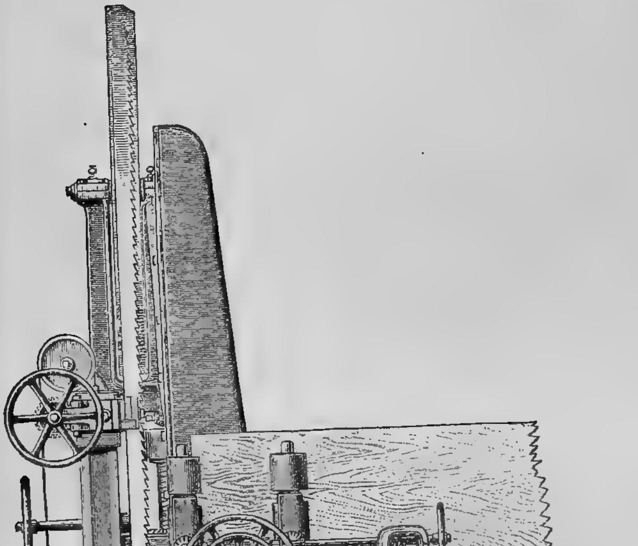


Fig. 380 *a*.

Photo-Engraving Co., N. Y.

Fig. 380 *b*.

thrust device and lateral guides above and below the cut, and straining device by weight and screw. The upper bearing slides in guided ways, and the arbor of the wheel has a screw adjustment to direct the course of the blade on the upper wheel. In a larger size, carrying a wide blade (Figs. 379 *a* and *b*), the saw-arbor cannot overhang. Therefore a telescopic link, adjustable by screw and chain-gearing, effects the adjustment of the arbor and maintains the tension of the saw. The outer pair of rollers yields by a weighted lever, the feed, as before, being by brush-wheels in front, which are adjustable by the hand-lever. The saw-wheels are of iron, with wooden rims covered with rubber. Special roller devices for the thrust are provided on these larger sizes.

Figs. 380 *a* and *b* show a similar type with the brush-wheels controllable from in front by a screw of steep pitch. The upper guide and thrust-bracket are counter-weighted and adjustable by hand-wheel. The brush-wheel pressure is adjustable by the weighted bent lever. The upper wheel-arbor is supported on both sides of the wheel. The rear feed-rolls yield with a weight to maintain the desired pressure. The band resaw has a variation of speed of feed up to 25 feet per minute. This makes it possible to do over four times as much work as with a reciprocating saw. The band-saw has a capacity for 10,000 feet per day, while the up-and-down saw will finish 2,500. The manifest advantage over the circular resaw is the use of thin blades of 14 or 18 gauge. It is possible to get two boards, sawed and planed, three-eighths of an inch wide, from a 1-inch board. The kerf and planer-chips all come out of one-fourth of an inch. For valuable lumber this is an important consideration, and it is for such materials that the band resaw has found its special application.

§ 38.

DIMENSION-SAWS.

After the lumber has been resawed to the desired thickness the next sawing operation upon it will be its reduction to the desired dimensions, either of width or length. For this purpose two saws will be used, known as the ripping- or slitting-saw, for sawing with the grain, and the cross-cut or cut-off saw for severing the fibers across the grain. For sawing with the grain, the teeth cut upon their front edges. Cross-cut saw teeth cut upon their sides. In ripping, the boards have to be fed against the saw; in cutting off they may be fed to the saw, or the saw may be moved across the work. The choice of these two latter methods will be governed usually by the size and weight of the piece to be sawed.

The usual bench-saw is a solid steel disk, with proper teeth in the circumference and a central hole for the driving-mandrel.

Fig. 381 shows forms of teeth of the two classes of saw. Inserted teeth are not extensively in use for this class of saw. The usual type of mandrel has the pulley at one end and the flange and nut for the saw at the other, the two journal-boxes lying between them and close to the points of strain.

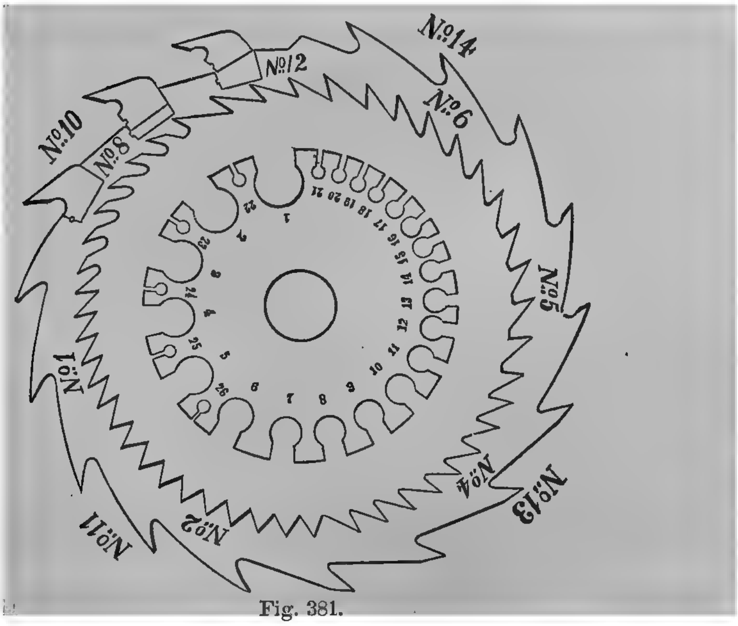


Fig. 381.

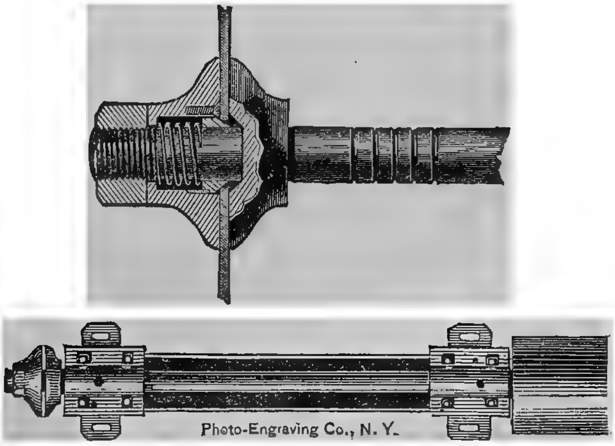


Fig. 382.

Fig. 382 shows a usual type. Most of the boxes are self-oiling to a certain extent, although the wisdom of intermitting the attention of the operator to his boxes has been questioned. A general type of these boxes would show an oil-cellar below the bearing, in which some fibrous material is put, which may hold the oil (Fig. 383). A diagonal groove in the bottom of the box carries the oil upward and to the ends, whence any excess flows back. The chambers at the ends of the box prevent any loss endwise, and a great saving is claimed and effected. The

mandrel shown prevents end-play by a series of rings turned in the journal, into which fit ridges in the babbitt of the box. The same figure illustrates a special cone-bushing, to simplify the centering of a saw whose hole is larger than the mandrel. The spiral spring in a hollow in the outer flange takes up all the play and the flange holds all from moving. A western builder tightens in a cone by a screw in the axis of the arbor. The pulley on the mandrel is made highly crowning to diminish the tendency of the belt to curl up and run off when bending so rapidly over so small a pulley. The pulleys must be small in cross-cut saws especially, in order that the work may pass over them. For this reason, too, the counter-shafts must be below or on the floor. For ripping-saws they may be overhead. The pulley must also be relatively wide. Its face is usually made equal to its diameter.

The saw-tables or saw-benches of to-day are of wood or of iron. The wood tables are made by several builders to supply a demand for a cheap article. The iron frames, however, are standard, as they should be.

Fig. 384 shows a type of wooden bench in which the top is made to lift by means of the cams under the front end. These are worked and held by a worm and wheel.

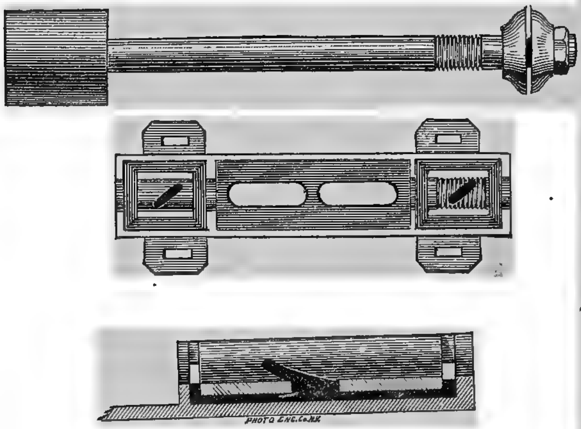


Fig. 383.

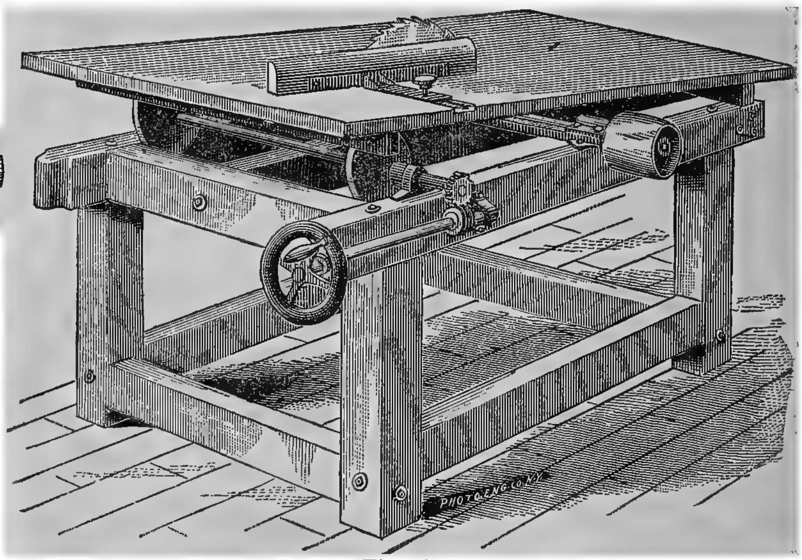


Fig. 384.

Fig. 385 shows an iron bench in which the whole table lifts bodily upon guides by a screw worked by the hand-wheel. One is for heavier and the other for lighter work. The object in varying the projection of the saw above

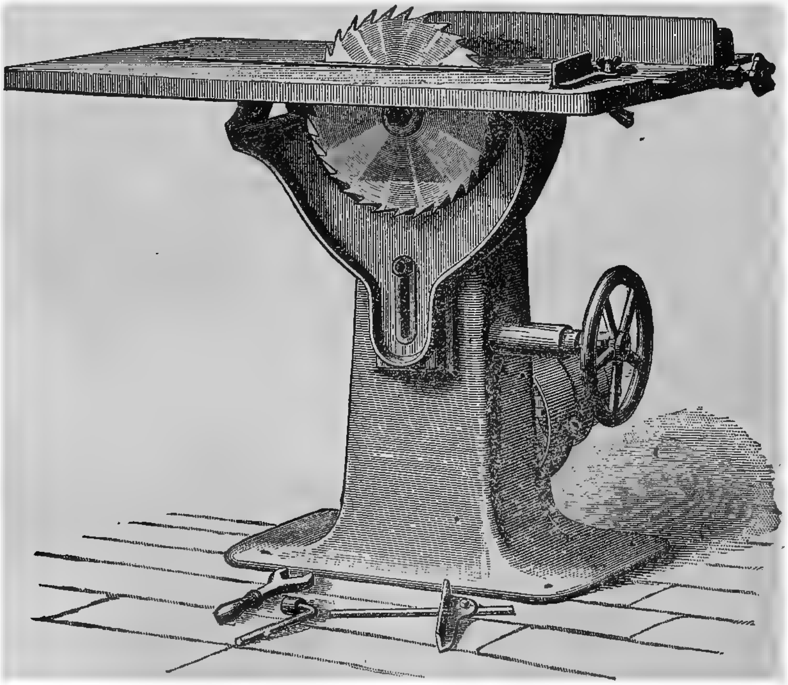


Fig. 385.

the table is to enable it to cut rabbets and tenons, or to make the cuts for gains. The wood is passed over it, and the saw cuts to the gauge mark. Round grooves may be cut in the face of work by passing it obliquely over the

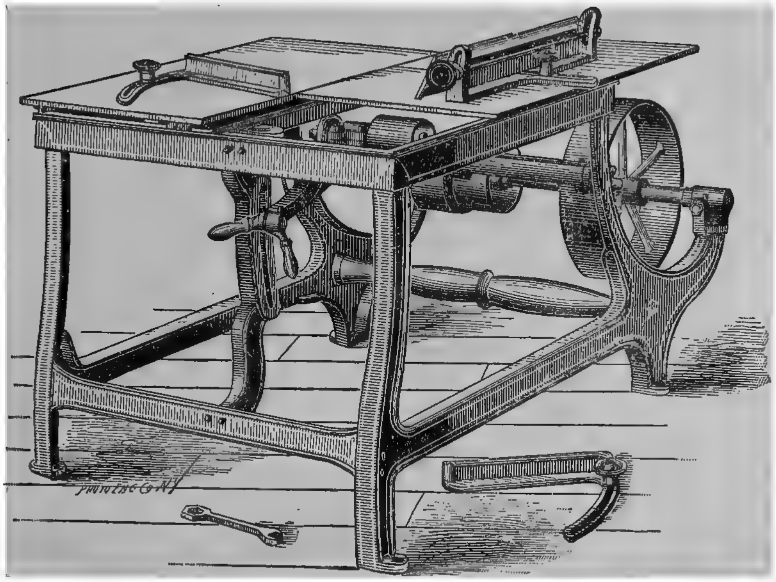


Fig. 386.

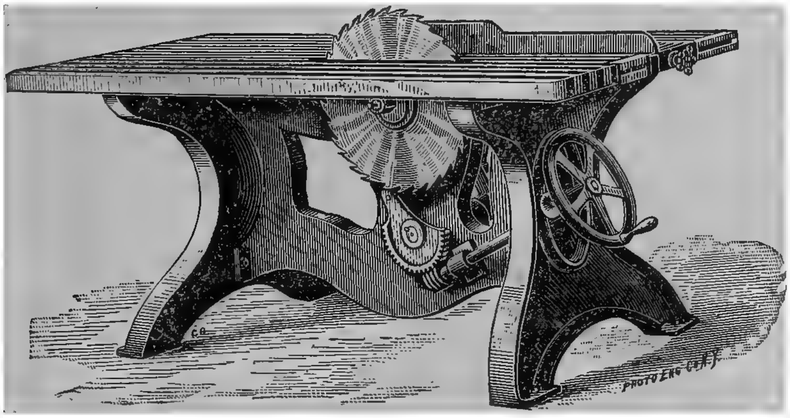


Fig. 387.

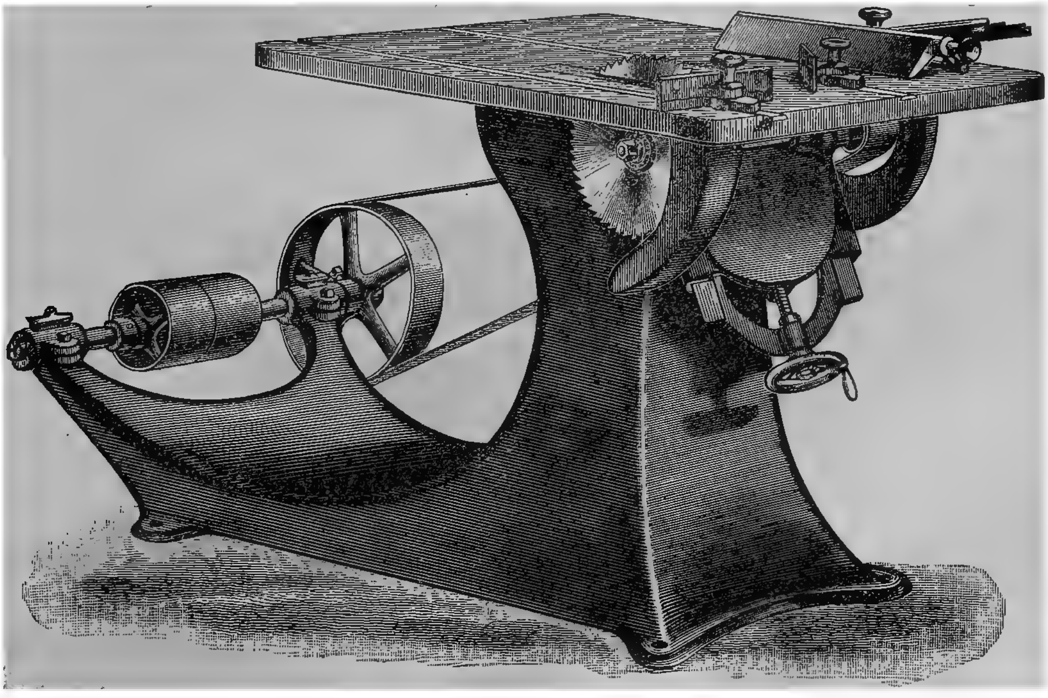


Fig. 388.

top of the slightly-projecting saw. All the best benches, therefore, of to-day have this adjustment, either lifting the table as above or by raising the saw-mandrel. In Fig. 386 the mandrel boxes are carried on a frame whose center of oscillation is the center of the counter-shaft. The arm and handle which raises and lowers the frame is clamped at any point of the slotted sector. In Fig. 387 the mandrel is controlled by the worm- and segment-wheel, and in Fig. 388 by the screw directly. These also illustrate the differences in design. The most modern practice approves the use of one single casting, by which stiffness is secured, and fewer joints in the frame.

For guiding work to the saw various arrangements of fence or rest are used. For iron tables a form such as shown in Fig. 389 has been used for splitting. The fence proper slides in the grooves of the rear part, which may

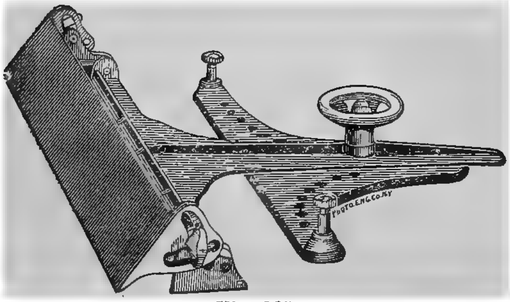


Fig. 389.

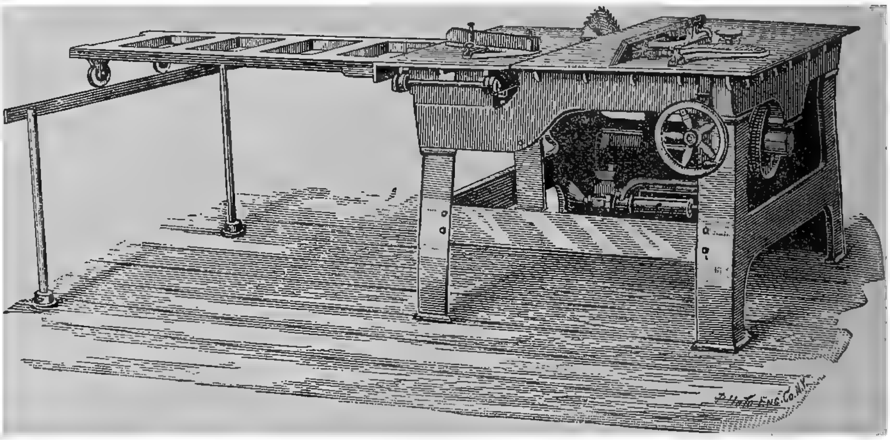


Fig. 390.

be pinned in holes in the table, so as to be parallel to the saw and at any desired distance from it. The fence can be clamped at any vertical angle with the plane of the saw for sawing bevels. In order to feed for cross-cutting a guide will be clamped at the desired horizontal angle with the saw and moved forward against the saw. The

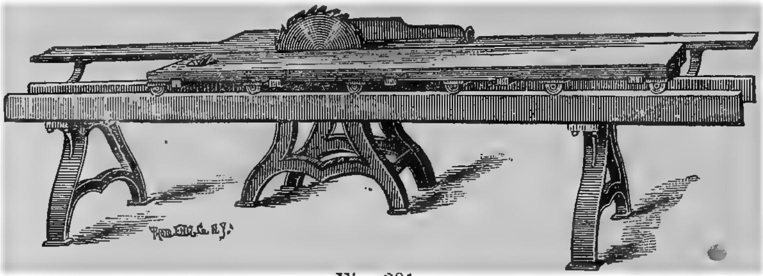


Fig. 391.

motion of the guide will be made parallel to the plane of the saw by a groove in the top of the table, in which fits a tenon on the bottom of the guide, or else (Fig. 390) the half of the table is made to slide upon ways with the guide

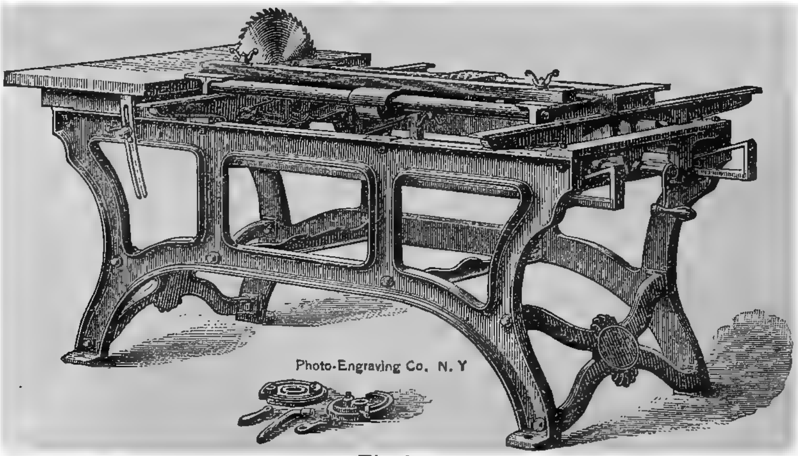


Fig. 392.

clamped upon it. The former method is usual upon tables with wood top, an iron groove being let into the top for the purpose.

Fig. 391 illustrates a roller-table for slitting-benches, designed for heavy plank, and Fig. 392 shows a table for

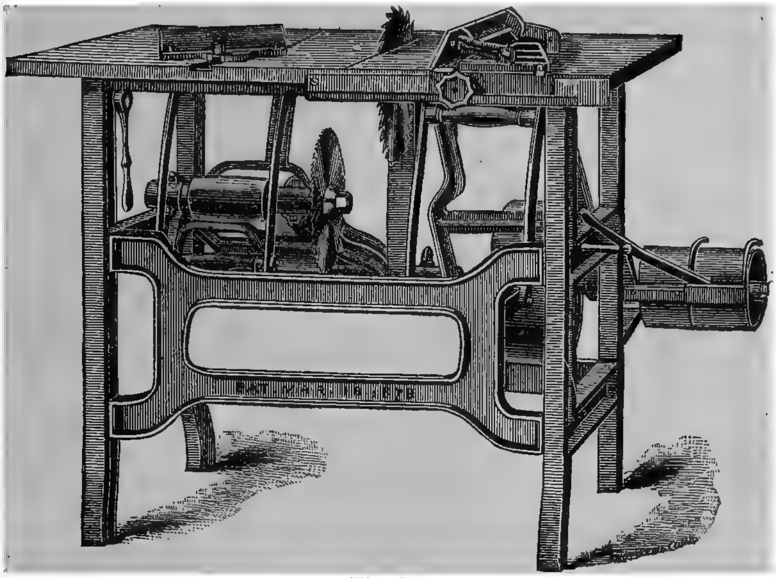


Fig. 393.

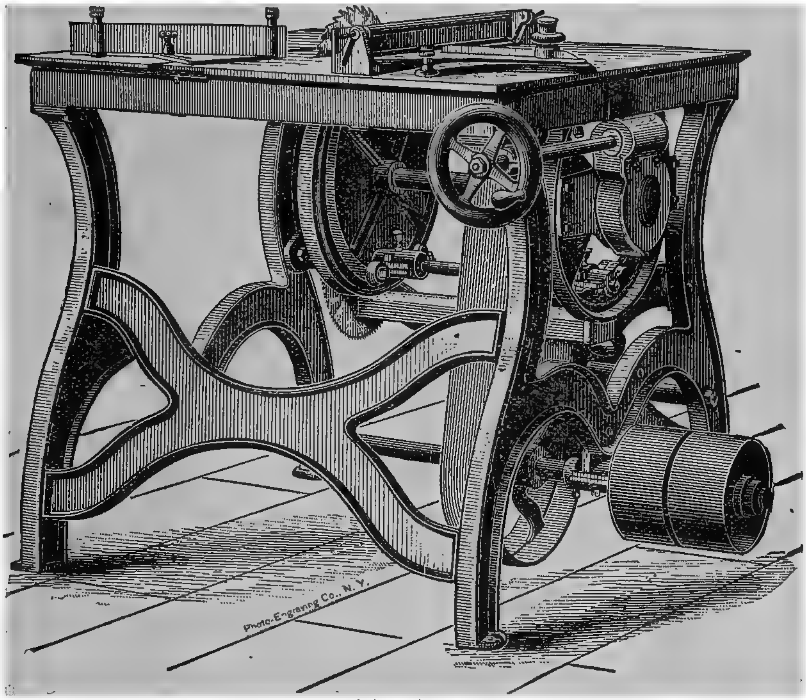


Fig. 394.

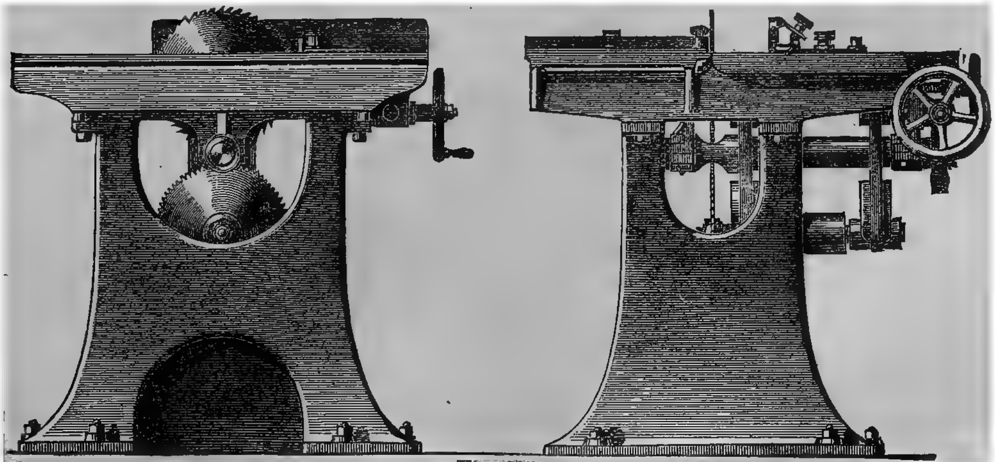


Fig. 395.

cutting off only. In this form the fixed half of the table may be inclined for bevels and the ways for the carriage may be lifted together by inclined planes for cutting across for tenons and gains. The crank at the right controls the inclines.

A very great part of the saw-benches for job or miscellaneous shops is made double, to accommodate at once a ripping and a cut-off saw.

Fig. 393 shows a double bench with adjustable saws, swinging in separate frames around the counter-shaft. There is a device to prevent both saws from being above the table at once, which is an element of danger. Its action can be suspended, however, if necessary. A more usual type of double table is illustrated by Fig. 394. The two mandrels are borne on opposite ends of a diameter in a frame, which receives a motion for adjustment around its center by a worm and wheel. Either saw may, therefore, be lifted up through the slit in the table and to any desired amount. It is a specialty of one or two to have the boxes of the mandrels remain right side up in all positions of either to avoid loss of oil. The driving-belt is made extra wide, and is guided so as to be in contact with that pulley which is in use in its every position.

Fig. 390 shows a similar design, and Fig. 395 illustrates a high-grade machine, built with great care and exactness for pattern-shops and the similar grades of service. The ripping-fence is adjusted by screw- and hand-wheel, and the other side of the table slides upon V's. The counter-shaft is at the base of the machine, so that the top is entirely free.

Fig. 396.

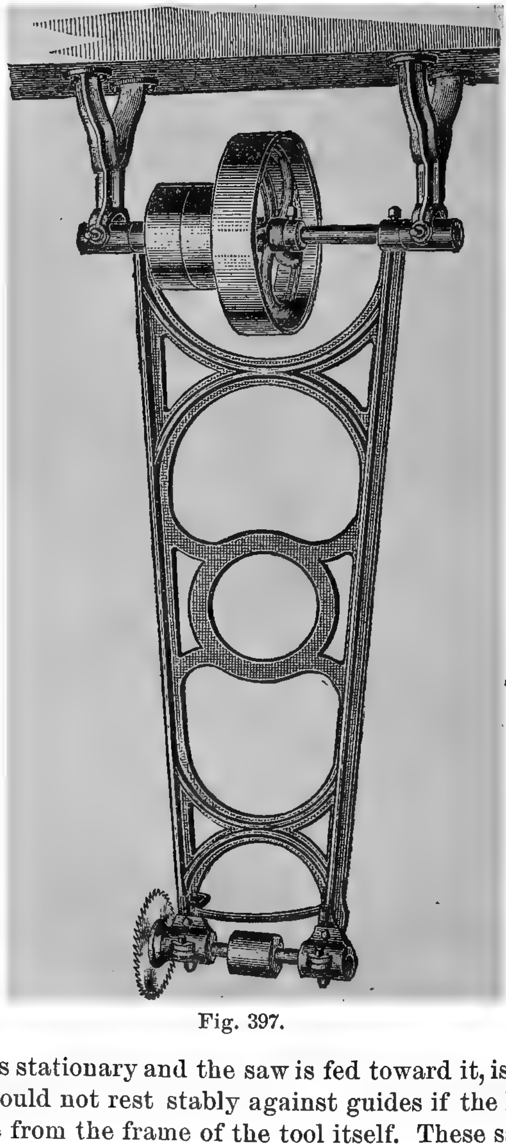


Fig. 397.

The other class of cross-cut saw-benches, where the work is stationary and the saw is fed toward it, is especially adapted for heavy work, or for work which, from its shape, would not rest stably against guides if the latter were in motion. The table for this class of saw is entirely separate from the frame of the tool itself. These saws appear in two forms. The cheaper and less exact is known as the swing cut-off saw, and appears in Figs. 396, 397, and 398. Fig. 396 shows the older form of wood frame, Fig. 397 is the improved iron frame, and Fig. 398 illustrates a shielded saw of neat design. The saw is borne on what is often called a yoke mandrel, receiving its motion from the counter-shaft, round which the frame swings. In the best practice the frame swings around the outside of the boxes of the hangers, so as not to bind the shaft. These may be arranged to hang from overhead or to come up through the table from below.

The better class of traveling saws is known as the railway cutting-off saw (Fig. 399). The saw-mandrel is borne

on a carriage, gibbed upon ways. The belt passes over guide-pulleys on a frame centered on the counter-shaft. This frame is linked to the carriage, and they move forward together. The driving is done by the under belt, and

Fig. 398.

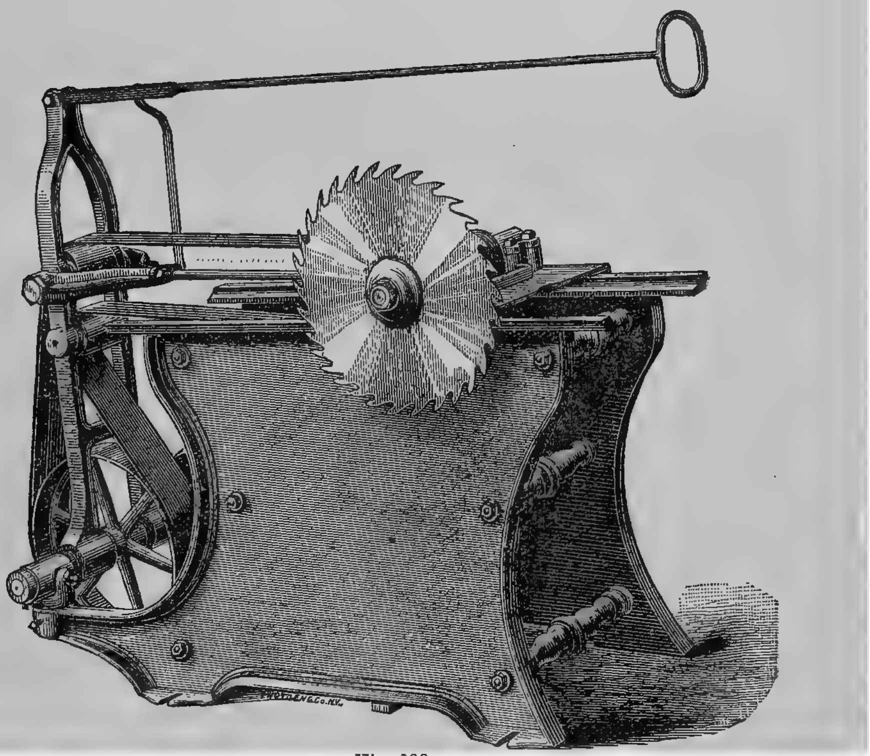


Fig. 399.

no difference is made in the strain of the belt within the limits of the travel of the saw. One maker links the frame to a pendulum in the way-frame, whose bob acts to retract the saw when the handle is released. The handle is always kept horizontal by the short link.

Fig. 400 shows a bracket railway-saw hung from a wall. The counter-shaft is overhead, over the center of the traverse of the saw. The bracket is mounted on a true plate, permitting adjustment for diminished diameter of

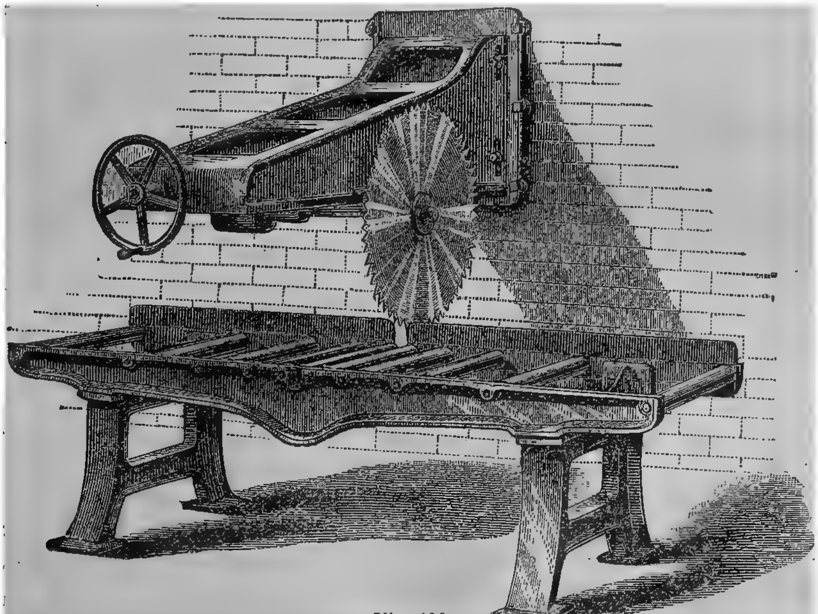


Fig. 400.

saw. The table has friction-rolls for the easy motion of heavy timbers. Not infrequently the tables are fitted with a scale of length from the saw-kerf as a zero-point, for convenience in cutting to dimensions.

There are devices upon the tables of several builders by which the adjustment of the ways of sliding tops is possible. This renders it easy to adjust to parallelism with the saw. Moreover, a tonguing or grooving head can be placed upon the saw-mandrel, where it may not be convenient to perform that operation on a special machine. Again, some table tops are arranged to tilt sidewise as a whole, for sawing bevels, and there may be minor modifications which are not of sufficient prominence to rank the table as a special machine.

§ 39

SPECIAL FORMS.

The circular-saw table may be adapted for one line of manufacture by very simple additions. It may be applied for cutting shingles from one or several blocks by adding a carriage, which shall reciprocate and give alternately unequal feeds to the ends of the blocks. It may be used for sawing to the center of small logs for clap-boards or to prepare the stock for ax-handle lathes and the like. The log is held on centers and rotated by an index-plate after each cut. A small core will be left, which can be used for other purposes. For cutting up cord-wood for railroad purposes a saw with a long mandrel is used, with a heavy solid balance-wheel near the pulley end. This is to store up work in the intermissions of cutting, so as to relieve the driving-power, which is very often a horse-tread power. For lath, fence, or flooring manufacture, or for general edging, a gang of saws may be used. For smaller work of standard thickness the saws may be spaced by distance-collars. These should be of a diameter sufficient to support the work at the level of the table. For miscellaneous edging, the saws are often upon grooved sleeves, which can be adjusted laterally on the splined or squared mandrel from the feeding-end. Very often these gang-edgers are arranged to be self-feeding. A serrated roller drives the solid wood in front of the saw, and a smooth pressure-bar holds the pieces from flying behind the cut. This may be also applied to a single slitting-saw. Two saws may be run on a single mandrel, for cutting off all pieces to a standard length, or the two saws may be on mandrels at an angle with each other, for producing a standard bevel at both ends of work. For sawing circular arcs from the plank two dished saws suitably spaced may be used. For sawing staves for barrels, either with or without bilge, cylinder saws are used. The block is fed and retracted from the saw on the proper lines automatically, while the staves are cut to the proper curvature. By setting a plain circular saw, of thick gauge, obliquely on its mandrel, it may be made to produce square grooves with considerable range of width.

Fig. 401 shows the use of oblique washers for this purpose, and Fig. 402 shows a different device. The latter may be adjusted very rapidly while the saw is in motion. The circular saw may also act as cutter for producing

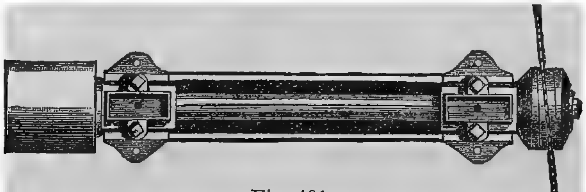


Fig. 401.

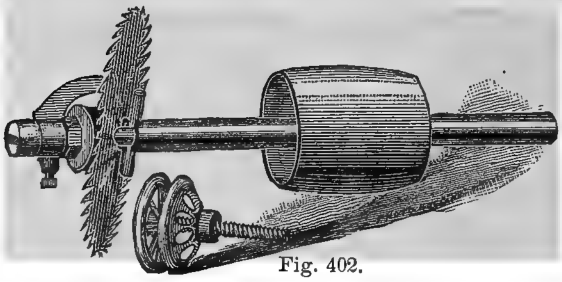


Fig. 402.

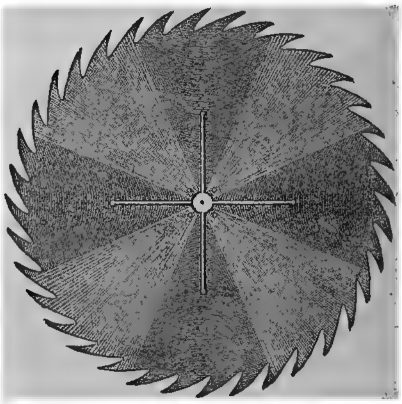


Fig. 403.

surfaces of revolution upon work revolved in front of it. When thickened or made of especial profile it may be applied as a kind of milling-cutter, for such duties as crozing barrel-staves and similar service. The great number of cutting-edges permits the saw to work very rapidly.

With regard to the manufacture of saws, the majority are made by the old process. The teeth are punched from the disks of soft steel, which are then hardened and tempered, and are then peined true with hammer on anvil. There is a New England manufacturer who claims advantages from his process of bringing the saws to form by pressure and heat under patented machinery. A western builder aims to avoid the difficulties of expansion and contraction by heat in service by radial slots in the plate (Fig. 403). These slots close when the blade tends to expand, and thereby the buckling and "wobbling" of the plate is asserted to be diminished. Bench-saws rarely use inserted teeth. They are employed more for forest practice.

§ 40.

BAND-SAWS.

The band-saw in its smaller sizes is not much used for dimension-sawing. While it can be so applied, it is for curved sawing that it meets its widest adaptation. Log-sawing and resawing are done with wide blades; scroll-sawing requires the use of narrow and thin blades. Of course the advantage of the band-saw over the jig or reciprocating saw is its continuous motion. This makes the presentation of work more easy and accurate, and the dust is carried down away from the lines of the marking. The advantages of the principle of the band-saw have already been noted.

The frame for the shop band-saw is now most frequently in one piece, cast in the form of a letter G, with cored or hollow section. In a few the arm carrying the upper guide is bolted on. The belt-wheels are of cast iron, or are built up of wrought-iron spokes and wooden rim, or are of composite design. Very often the two wheels are of different designs. The lower wheel is the driving-wheel, and may be made heavy, since its inertia can do no harm to the saw. The upper wheel, however, is an idle-wheel for maintaining the tension of the saw, and should be as

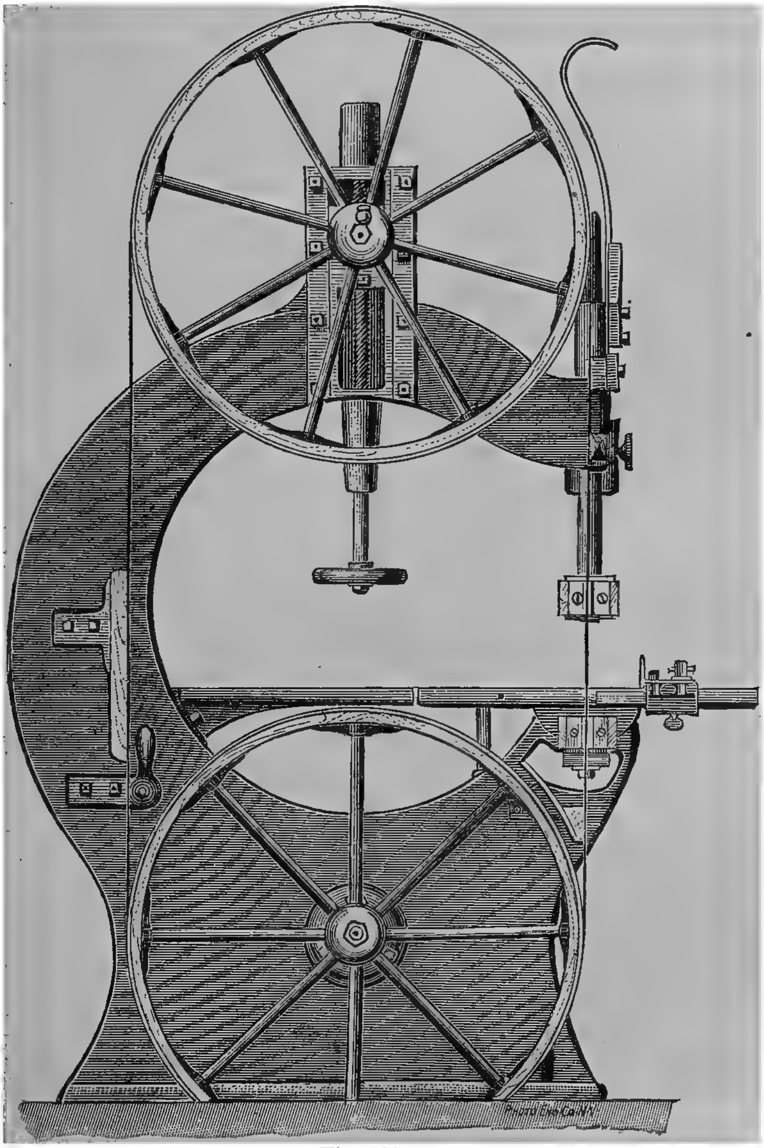


Fig. 404 *a*.

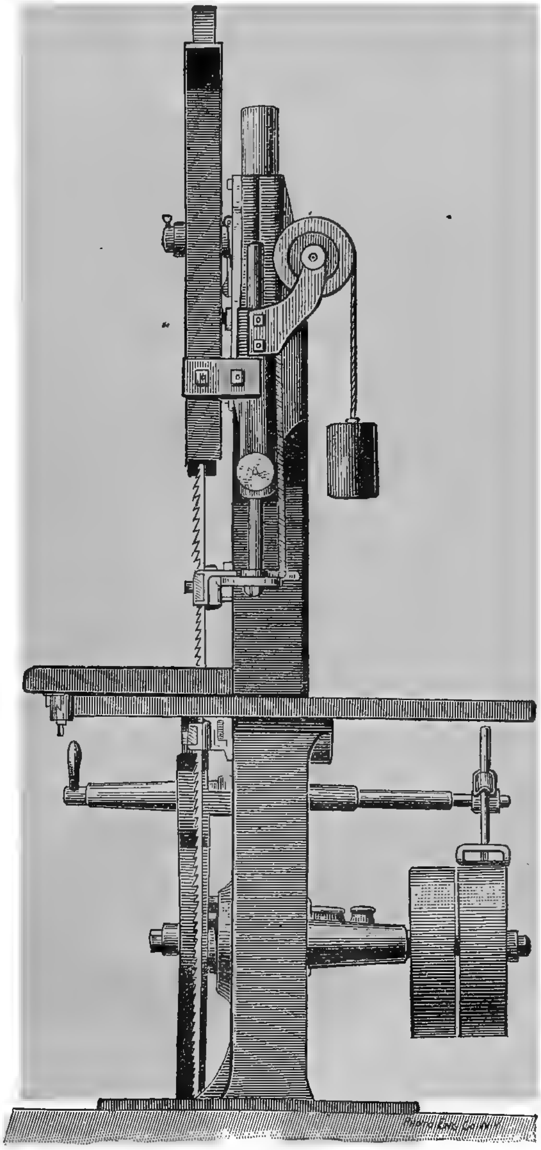


Fig. 404 *b*.

light as possible. The reason for this lessening of inertia and living force in the upper wheel is very obvious. When the lower wheel is started by shifting the belt upon the fast pulley the saw at once tends to start at full speed with it. In putting the upper wheel in motion the saw will be stretched and will slip over the upper wheel till its inertia is overcome. The greater its dead weight the more the slip. When the belt is shifted off the fast pulley, the friction on the lower shaft, due to the strain of the belt on the loose pulley, will arrest the motion. The

upper wheel having less friction would be likely to overrun the saw, straining it or slipping under it. The tendency to overrun would also occur when the work of the saw grew harder and it moved more slowly for a time. The slipping of the saw or wheel tends to heat the saw and ultimately to deteriorate it or to wear the covering of the wheels. For these reasons special features of upper wheel will be noted. The saw is strained by the adjustment of the upper wheel. Its bearings are borne in a slide which rises and falls on a screw. This permits a variation in length of the saw of several inches. For maintaining the tension of the saw under slight variations of length, due to stretch or temperature, a weight or spring is applied to the adjusting-screw. The weighted lever is most approved, being easily adjustable and positive. Rubber springs are apt to become stiff by cold and by long service. To guide the saw upon any part of the face of the upper wheel the mandrel is made to tilt. This is usually done by a hinging apron lifted by a set-screw. Some of those in which the plane of the guides is at right angles to the way in which they stand in Fig. 404 had the adjustment for the plane of the wheel in a horizontal plane. The former is approved, however. The wheels are covered with leather or rubber, to preserve the set of the teeth of the saw. Another very essential feature in the shop band-saw is the guide and thrust device at the cut. This must prevent the saw from twisting on curves and from yielding to the pressure of the cut.

Figs. 404 *a* and *b* show a saw strained by screw and spring. The top guide is counter-weighted and clamped close to the cut. The lower guide is just below the table. In this tool the thrust is taken by a steel washer set forward by a cylinder of cast iron for blades of different widths. The washer may be rotated as it wears. The side guides are adjustable for different thicknesses and confine the washer.

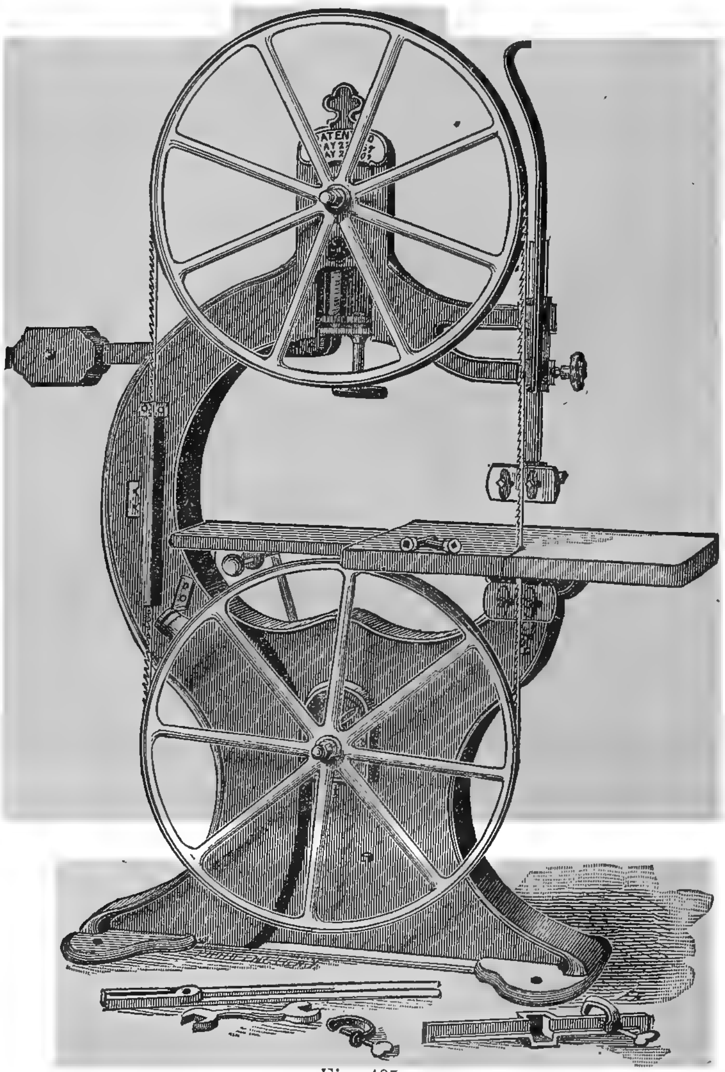


Fig. 405.

Fig. 405 shows the arrangement for straining the saw by a weight. The thrust is here borne by a steel plate, which is adjusted by four set-screws, so as to have a true bearing against the blade. The side guides are of wood. A brush keeps the sawdust from adhering to the rubber tire.

Fig. 406 has a weighted lever to strain the saw, which has a stop so that the tension may be taken off when not required. The thrust is here taken by a steel rod in place endwise behind the saw. It is adjusted by a milled head behind the guide bar. Side guides are of wood. This tool has a guard, C, below the table to carry off blocks and dust from the saw.

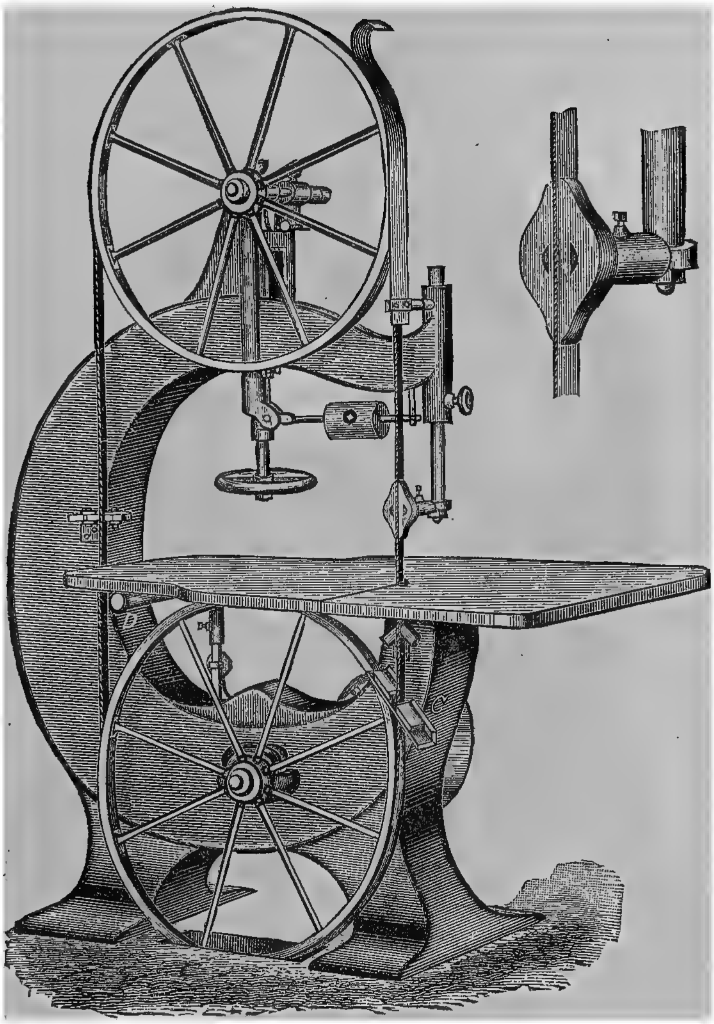


Fig. 406.

Fig. 407 illustrates a design with cast-iron driving-wheel below and an elastic steel wheel of very light construction above. A similar weighted lever takes up and compensates for any buckling or stretch of the blade, and the thrust is borne upon a steel roller with wooden side guides. The roller device diminishes the tendency for the back of the saw to upset or harden. The objections to it are its high speed of rotation, and that the support to the blade must be at a point above the cut distant at least the radius of the roller. This roller is also apt to "ring" or become cut into grooves. There is a roller at the rear to guide the blade to the upper wheel, and the ascending part of the blade is shielded. The guard in front of the upper wheel is universal in order to prevent injury in case of accident. The roller thrusts are lubricated by self-oilers. There is a brake connected to the shipping device to arrest the motion quickly. The rubber tire of the wheel is ground true in place.

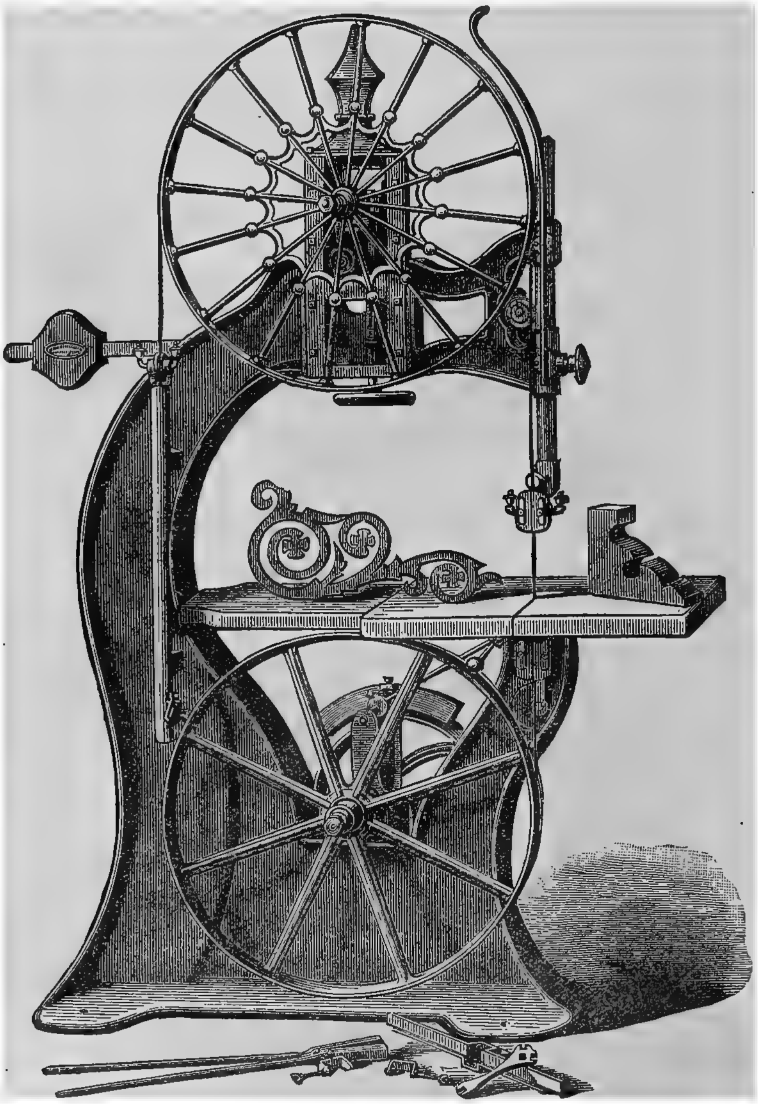


Fig. 407.

Fig. 408 has the mandrels supported in boxes upon their ends, instead of permitting the wheels to overhang. The counter-weight acts directly in the plane of the saw, so that its action does not bind the slide, and therefore it is more sensitive. The thrust is taken by a hardened steel disk whose center is out of the plane of the pressure against the saw. The grooves cut by the back of the saw do not intersect at one point, and the washer can be turned to present a fresh surface until it is all used up. The rotation is by a worm-thread cut on the edge of the disk.

Fig. 409 illustrates a type of slightly different shape of frame. The adjusting-apron swings laterally by set-screws to produce vertical adjustment of the upper wheel. The geared tension-screw is counter-weighted. The lateral guides are of wood. The thrust of the cut is taken upon a series of balls of hardened steel. These rest in a drilled vertical cylinder, and are kept from contact with each other by steel-drilled washers of the same diameter. The balls are set up against the saw back by set-screws, whose points bear against the balls a little at one side of the line of saw pressure. As the balls are turned by the saw a compound motion is caused by the bearing of the screws, and therefore the balls are prevented from "ringing". This ball system distributes the pressure against

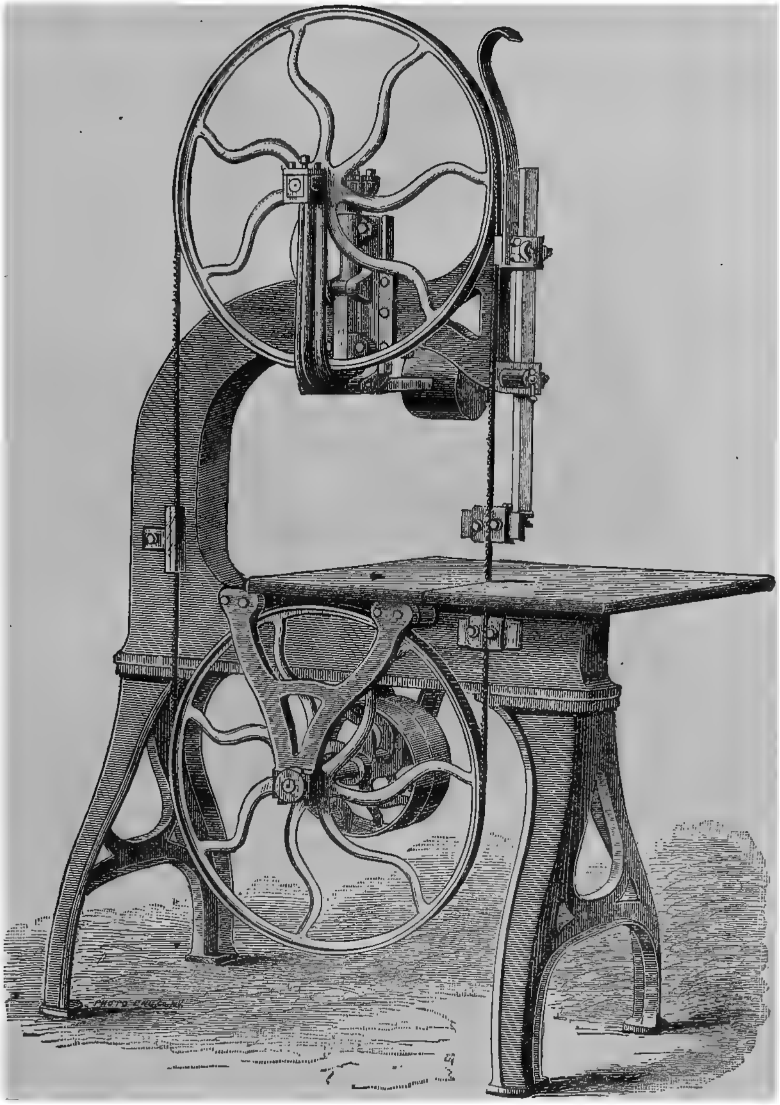


Fig. 408.

the blade over a large area and brings the first resistance close to the cut. To counteract the strains on the saw, due to starting the upper wheel and to its overrunning when the lower wheel is stopped by a friction-brake, this machine has a special device. The rim of the upper wheel is flanged, and pockets of anti-friction alloy are formed in recesses in it. In the groove thus formed a steel ring covered with leather is accurately fitted. The saw lies upon this ring, the leather serving to protect the set of the saw. This light ring will slip in the groove at the start

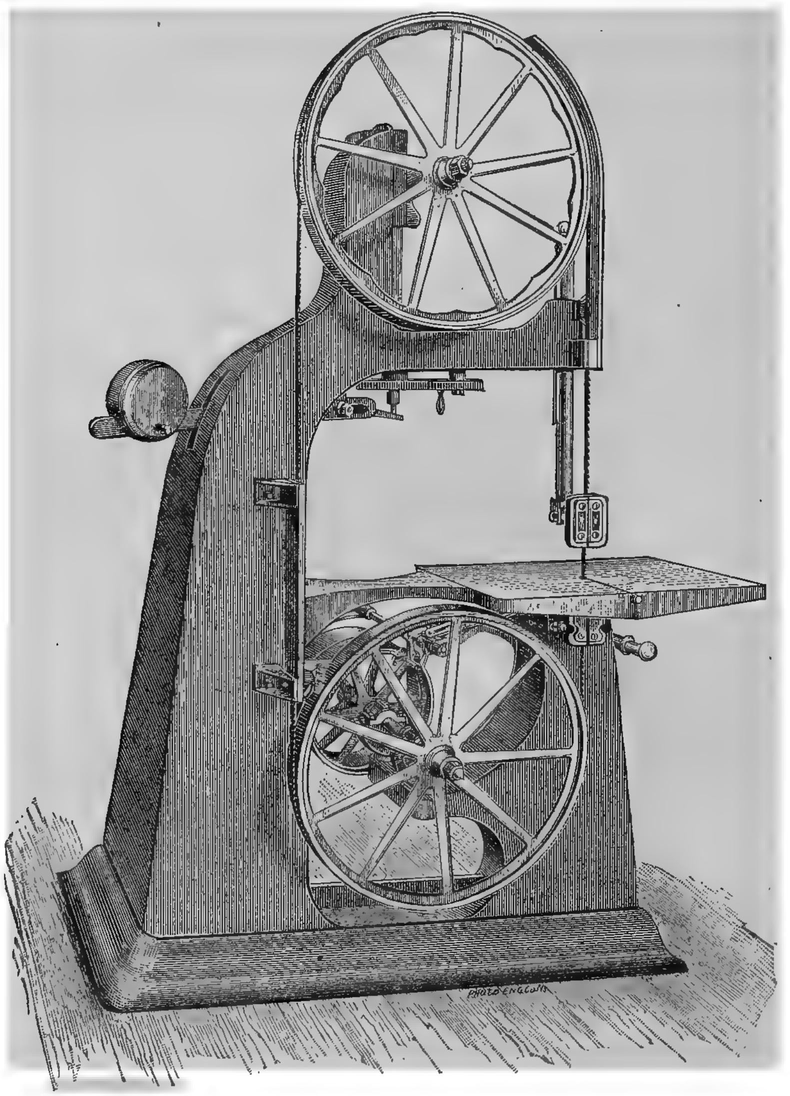


Fig. 409.

or the arrest of motion and distribute the shock of change over several inches of circumference and between smooth surfaces. Otherwise the saw-teeth must rough up the covering of the wheels. The centrifugal expansion of the ring gives elasticity to the bedding of the saw. The friction-brake clasps the pulley-face on both sides and stops rotation rapidly without forcing the wheel out of line. The links to the brake from the shifter-lever are so arranged that the saw is not liable to be freed accidentally and to be started while the operator is handling it. The brake-lever will have passed its dead-point, and will be so held locked by the bearing of the shifter-rod when the brake is acting and the belt is on the loose pulley. The chattering of the shifter-fork cannot disengage either shifter or brake.

There is a variety of cheaper designs with omission of the special features of excellence in the larger patterns. The strain on the saw may be by screw only, without spring or weight; the thrust may be by wood only; the table may be fixed without arrangements for bevel sawing, and less care may be taken in fitting. These are in answer to a demand for low-priced goods, where durability and accuracy are thought of less moment.

§ 41.

RECIPROCATING SCROLL- OR JIG-SAWS.

A continuous saw is not adapted for fret-work, in which internal patterns are to be cut out. It becomes necessary to have a saw of which one end may be inserted within the area to be removed. The band-saw must therefore be supplemented or replaced by a reciprocating saw, which shall have one end which may be freed from the driving mechanism. These saws appear in three forms: Gate-saws, strained saws, and unstrained saws. The gate-saws are adapted for scroll-work upon heavy plank. The saw is strained positively by a screw between an upper and lower frame, which receives motion from a wrist-plate shaft. There may be one saw, as in Fig. 410, in the center of a wide table, or the post-gate system of Fig. 411 may be duplicated upon the other side of the post. Each saw in this case resists the strain of the other. The thrust and twist of the cut is resisted by an adjustable guide, hung from the stationary frame. This also holds down the work on the up-strokes. A reciprocating air-pump blows the lifted dust from the lines in Fig. 410. Centrifugal blowers are more usual.

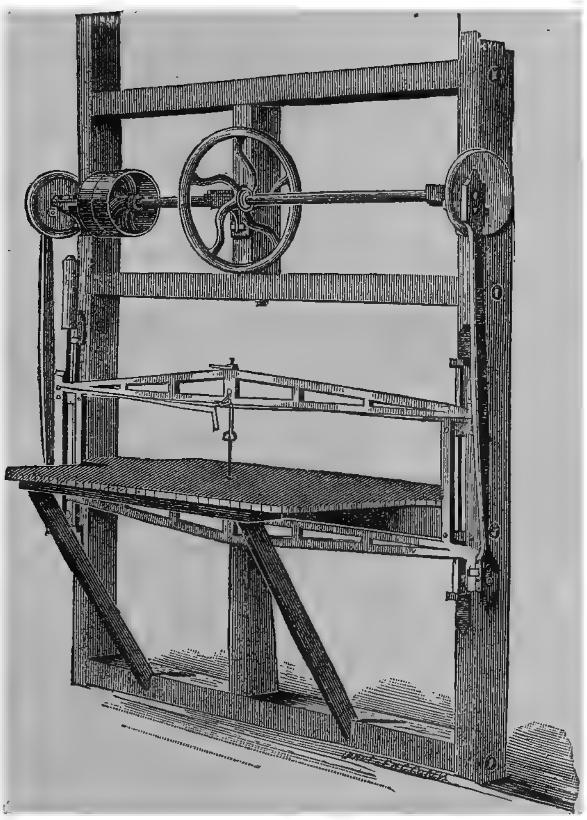


Fig. 410.

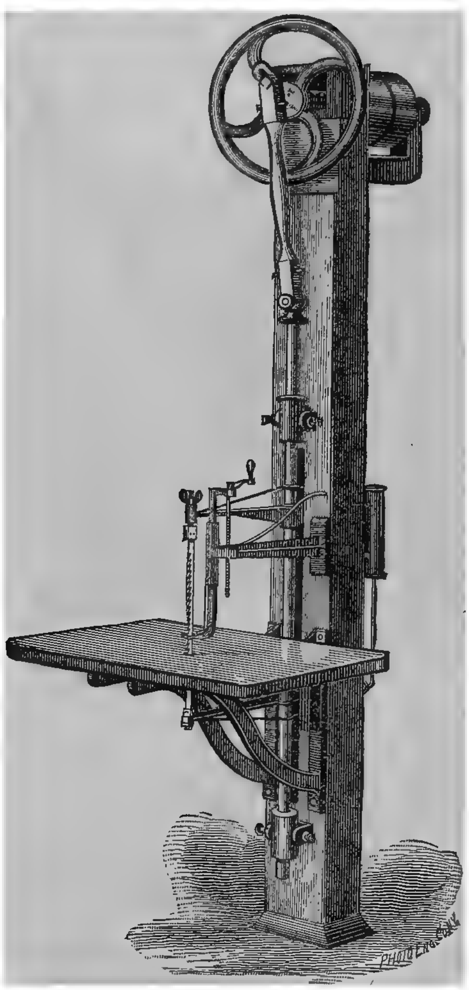


Fig. 411.

In Fig. 410 the trussed frame is so long as to require light lateral bracing. In the post-gate system the central connection makes this unnecessary. In the form shown the slide is of gas-pipe, for the sake of the lightness. The fly-wheel equalizes the work upon the two strokes.

The saws strained with a spring are by far the most numerous. Since they cannot be forced to heavy cuts as in the gate-saws, they must acquire their capacity by very high speeds. The reciprocating parts are therefore made very light, and the spring is made strong enough to carry up the saw, which cuts on the down-stroke only. The great advantage which this type has over the gate-saws is its wide swing. The upper works above the saw are attached to a hanging post, braced by rods to the ceiling. These tie-rods are usually made adjustable by turn-buckles or right-and-left sleeves, which may make the post entirely rigid and insure that the saw is perpendicular to the table. The lower end of the saw is guided by a cross-head, which is driven by a light wooden pitman from a wrist-plate shaft near the floor. This shaft carries a fast-and-loose pulley, the shifter, in many modern designs,

being worked by the foot of the operator. Almost universally the shifter device applies and releases a brake upon the edge of the wrist-plate. A great saving of time results from this. The wrist-plate is made heavy to serve as balance-wheel.

The old form of spring to lift the saw was a bar of ash secured at the end farthest from the saw. This wood spring, when used to-day, is either made duplex or else acts on the saw through leverages. Either system reduces the length and inertia of the spring and permits a higher speed of reciprocation. The problem of straining devices of to-day is to secure equal tension of the saw at all points of its stroke. A large number of designs use the fusee principle, by which the leverage of the saw diminishes as the strain on the spring grows greater. The leather strap to the saw or to the spring is wrapped and unwrapped spirally upon a cone or an eccentric-wheel or arc. Very many are content to attain this object, and permit very high speeds by permitting but small motion to the spring.

In Fig. 412 a spiral spring acts upon the pivoted arc, upon whose face is stretched the flexible band to which the saw is hooked. The arc keeps the pull on the upper cross-head vertical.

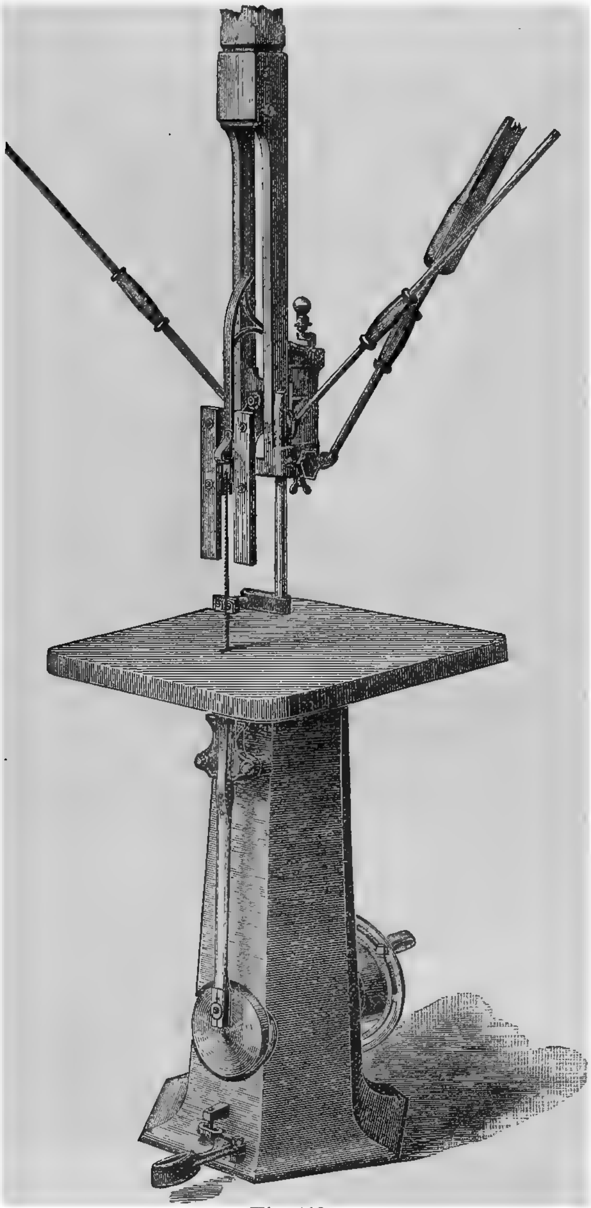


Fig. 412.

Fig. 413.

In Fig. 413 of a tool by the same builders, the springs are open ovals of thick steel, strained by the levers shown. Their varying leverage equates the varying strain on the springs. Differences of tension are secured by the position of the ovals under the clamping set-screws, and the whole upper casting is also movable for further adjustment. Direct torsion of steel bars is also applied by some designers. The form of table is also adapted to absorb its own vibrations instead of transmitting them to the flooring. So important a consideration is this of absorbing vibrations properly, that some of the older forms should not be put on the upper floors of high buildings.

In Fig. 414 the strain is maintained by leaf springs acting on a differential-wheel device within the shield. The springs may be equalized by the milled-head screws. The shifter-brake acts by an incline and is very powerful. Such a machine may be run at from 1,600 to 1,800 revolutions per minute.

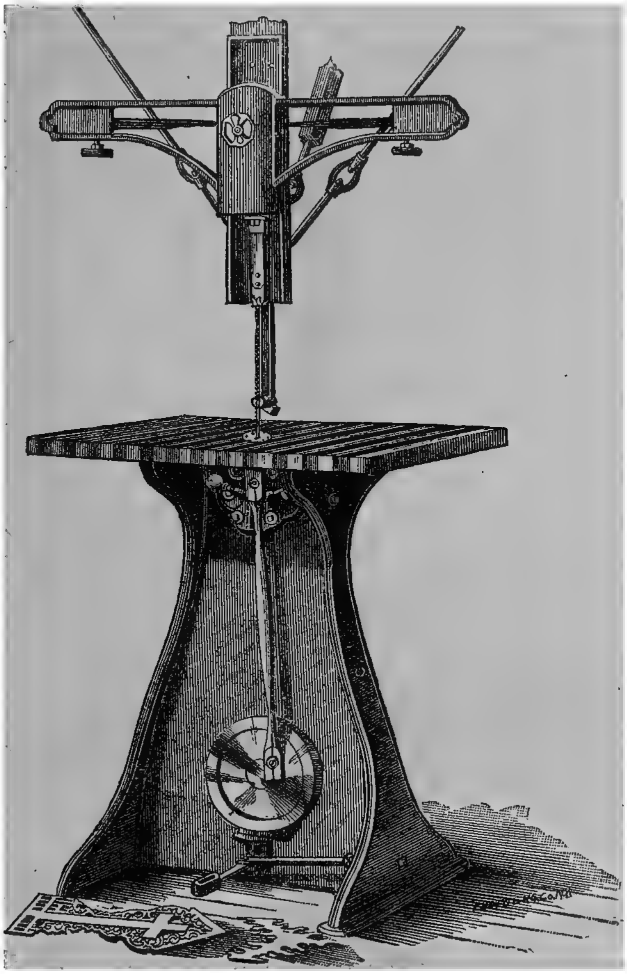


Fig. 414.

Fig. 415.

Fig. 415 shows a coiled-spring lever-strain, with the strain on the saw adjustable between the limits of 10 to 75 pounds. All the upper works are carried by the pipe E, and they are balanced by the spiral spring O above them. The shaft E is clamped at will by the cam-lever F. The air-pump is within E. The lower cross-head has special devices to prevent jamming or rattling from heat or contraction, and the friction devices for the crank-shaft permit the machine to be stopped, the saw to be removed, replaced and in operation within four seconds. The tilting of the table of a larger size is sometimes convenient for sawing patterns with draught.

Fig. 416 shows a saw in which the straining-lever floats upon the links to the two straining-springs. The relative variation in the leverages of the two springs keeps a uniform tension on the blade. The degree of strain is controlled by the thumb-screw.

Fig. 417 shows a form of unstrained saw on the mulay principle. The slide below is octagonal and hollow, and the saw is pinned to it by spring cotters. The upper end is free, and the thrust is received and the blade is guided just above the work. The guide also acts as a "hold-down" for the work. The fan-blower is above the foot-socket of the hanging post. Such saws may run very rapidly, and avoid the inconvenience of the overhead springs and their wear and fracture. Perforated work is also done very rapidly where no disconnection is required. They will cut quite heavy pieces for carriage, wagon, and miscellaneous work. The strained fret-saws of the same builder are so arranged that the rake of the cut may be varied by throwing forward the cross-head guides. Wooden tops are often fitted with an iron plate around the saw, that a hollow place may not be worn there. Wooden tables are often made of ash and walnut or cherry glued in alternate strips, to prevent a tendency to warp. Most builders have patterns for tables which may tilt for bevels.

There is an infinity of jig-saw attachments to be put upon lathes. These are for amateurs entirely, and for pleasure rather than for profit. They do not come within the scope of this discussion. Neither do the reciprocating saws for forest sawing. They are discussed elsewhere.

In concluding the subject of the reciprocating saws, it may be said that their importance has been waning

since the introduction of the band-saw for outside work and of friezing or shaping cutters for inside ornamentation. The latter finish the surface as well as shape it, and for many classes of work are superseding the scroll- and fret-saw. The latter must, however, be still employed until the type of ornamentation for certain work shall undergo a considerable change.

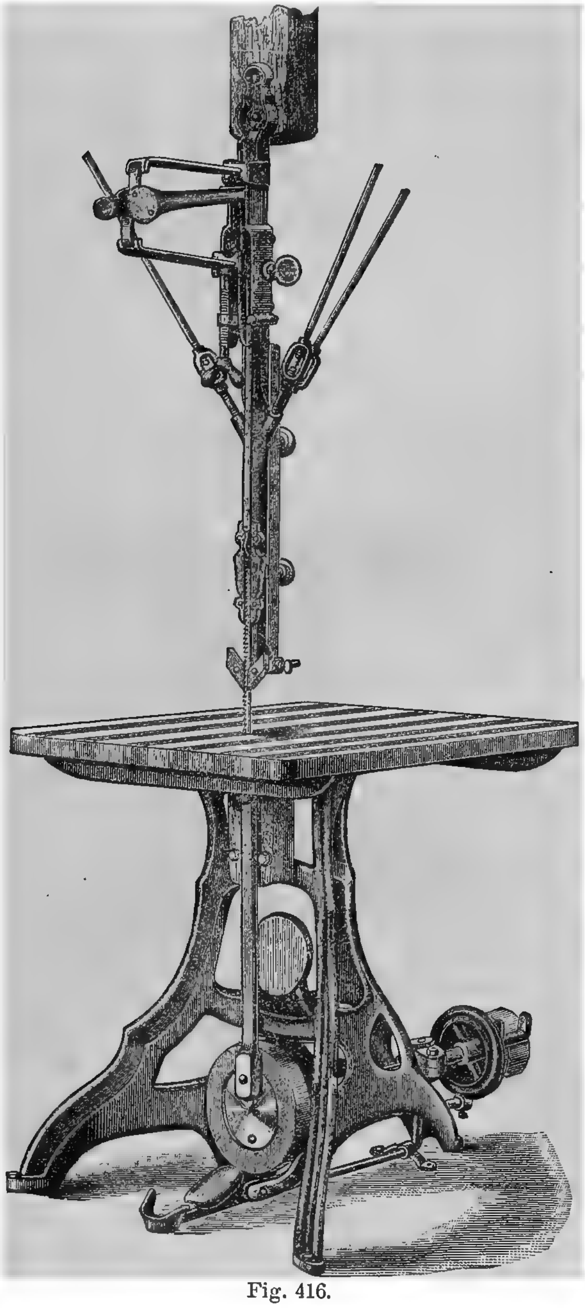


Fig. 416.

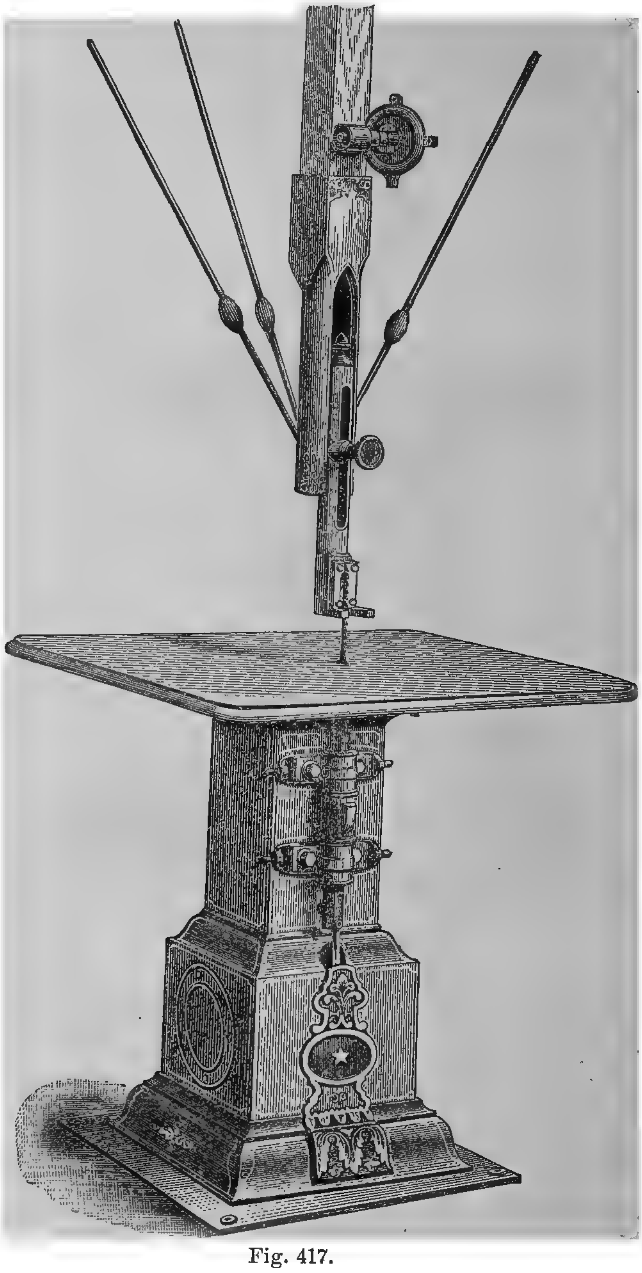


Fig. 417.

Sawing machinery as a class is fundamental to the other processes. Considerable thought has been expended in improving it, and the results are to be seen in the types illustrated. The improvement since the earlier days is very marked, and is daily advancing.

§ 42.

G.—TOOLS ACTING BY PARING.

SURFACERS, PLANERS, AND MATCHERS.

After the wood has come from the resaws, or from the forest-saws, its surface is rough. It will have the marks of the saws upon it, it may be gritty and disfigured, and it may be in wind or out of truth. It is therefore passed through a machine, in which cutters act upon it in the direction of its fibers or grain. The edges act to pare away the surfaces, taking off chips, and not dust. A class of machinery, therefore, very different from the

saws results from this difference in the direction of the grain relatively to the cutters. The cutters will be fewer in number, but with longer face; the feed-motions will always be by power, and special devices for steadying the work and preventing splitting will be necessary. Where, beside the production of surface, the tool must bring to exact plane dimensions, a carriage or dimension-planer will be required. For ordinary board work, which is yielding, a surfacer is used.

Surfacers may be of two kinds: the bed may be stationary while the stock passes over it driven by feeding-rolls, or the bed may travel under the revolving cutter, carrying the stock with it. The larger tools are of the first class, with stationary bed; many small ones are now built with the traveling bed. There is also a difference due to the method of adjusting for thickness; the rolls may rise or the bed may fall. The surfacing-cutters are knives of a length suitable to the size of the machine, which are bolted to flat surfaces on a cylinder. This cylinder is made to revolve rapidly, while the stock passes against the revolving edges. These knives are of an appearance and shape shown by Fig. 418. The slots are for the bolts which fasten the knife to the cylinder. In that form there is

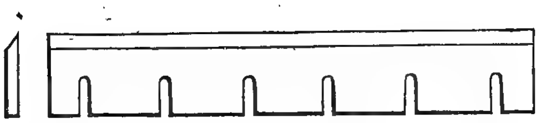


Fig. 418.

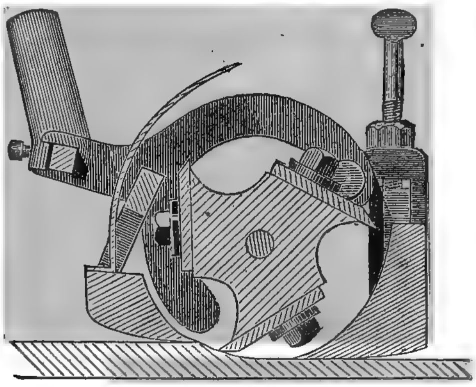


Fig. 419.

chance for adjustment, as the knives are ground narrower. The cylinders carry either three or four knives usually. The flats for the knives are shaped so as to act as a cap or chip-breaker. The cylinder is made of forged steel in the best practice, all in one piece. Very good results are obtained by the use of wrought-iron bodies, into which the spindles are forced or shrunk, and one builder casts the body around the spindle, using a so-called welding compound to effect the joint. The planing of T-slots in the faces of the cylinder for the heads of the knife-bolts is best practice. Many builders plane slots in two sides, and have the other two sides with tapped holes only. Some have no slots, but tap all holes. This obliges all knives to have equally-spaced slots, and twisted bolts or stripped threads are serious annoyances. This cylinder, with its knives, is driven at 3,000 to 4,000 revolutions per minute. Inasmuch as the cutters turn against the incoming stock, some form of pressure-bar is required to prevent the splitting of the surface in front of the cutter and to steady it after it leaves the cutter.

Fig. 419 illustrates an approved form of bar on each side of a three-knife cylinder. The stock is moving from left to right, while the cutting-cylinder turns in the direction of the hands of a watch. The front bar rises upon an arc of a circle around its pivot, behind the knife. This pivot is raised with the adjustment of the cylinder-boxes, and the bar always swings in an arc close to the cut. Some use a roll for a pressure-bar and have a separate pressure from the shaving-guard to serve as chip-breaker. The rear pressure-bar is either stationary or rises and falls beneath rubber compression-springs, which are adjustable. Some claim a yielding bar produces waves in the surface. Weighted levers are used for the front bar in most frequent practice. In the design of Fig. 432 the pressure-bar is pivoted on the outside of the cylinder-boxes, so that the lip of the bar is always one-fourth of an inch from the cutting-edge of the knife. A handle rests on the feed-rolls to prevent an extra-thick piece from catching on the corner of the pressure-bar. A few use rubber for the front bar as well as for the rear. In another design the bars rise and fall in grooves struck from the cylinder center, and so keep the bars close to the cut. The reason for seeking the closeness of these bars is that the knives may cut short pieces without striking the first end or spoiling the last end. The machine with this latter device has planed a 2-inch square of black walnut, and has reduced a slip of white pine from nine-sixteenths to one-sixteenth of an inch.

A few use a large friction-roller under the knife, to relieve the friction due to the downward pressure of the cut. This is opposed by some of the best builders, on the ground that the board bends over the roll if the latter projects enough to be of any use and the work will not be true. That this pressure downward is considerable may be proved by the fact that the tables are apt to wear hollow at that point. The design of Fig. 420, which is shown in detail by Fig. 421, and to which also Fig. 419 belongs, has a false plate below the cylinder, which may be renewed when worn. Often a strip of steel is let into the table at that point.

Fig. 421 shows one method of connecting the boxes at the two ends of the cylinder. The cylinder and knives in the first class of machines, with roll-feed and stationary table, must have a vertical adjustment for different thicknesses of work. The boxes, therefore, are fitted to move up and down and clamp in planed ways. This vertical adjustment is effected by screws, which are geared together by a shaft across the bed with bevel-gears

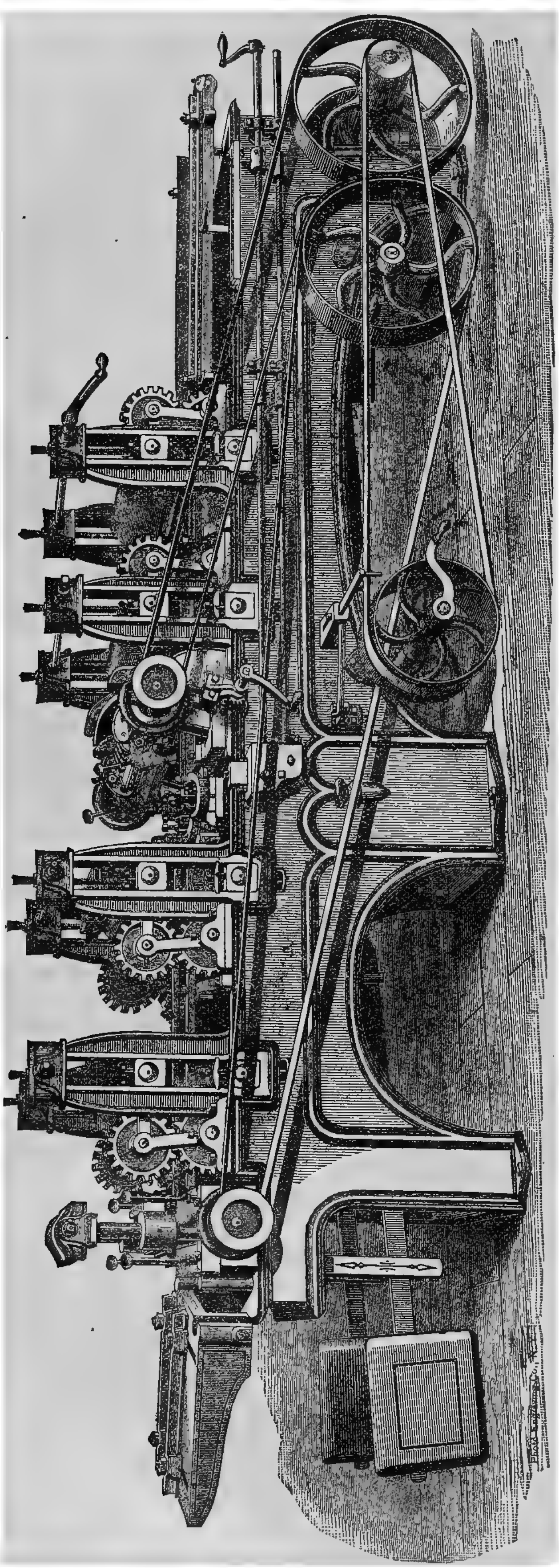


Fig. 420.

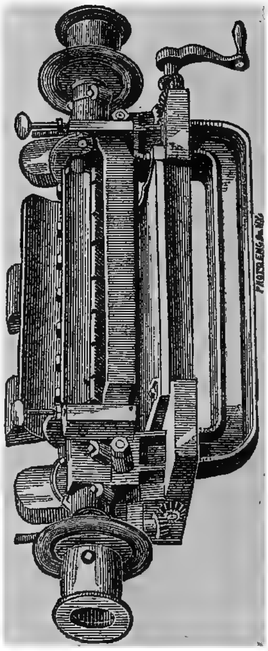


Fig. 421.

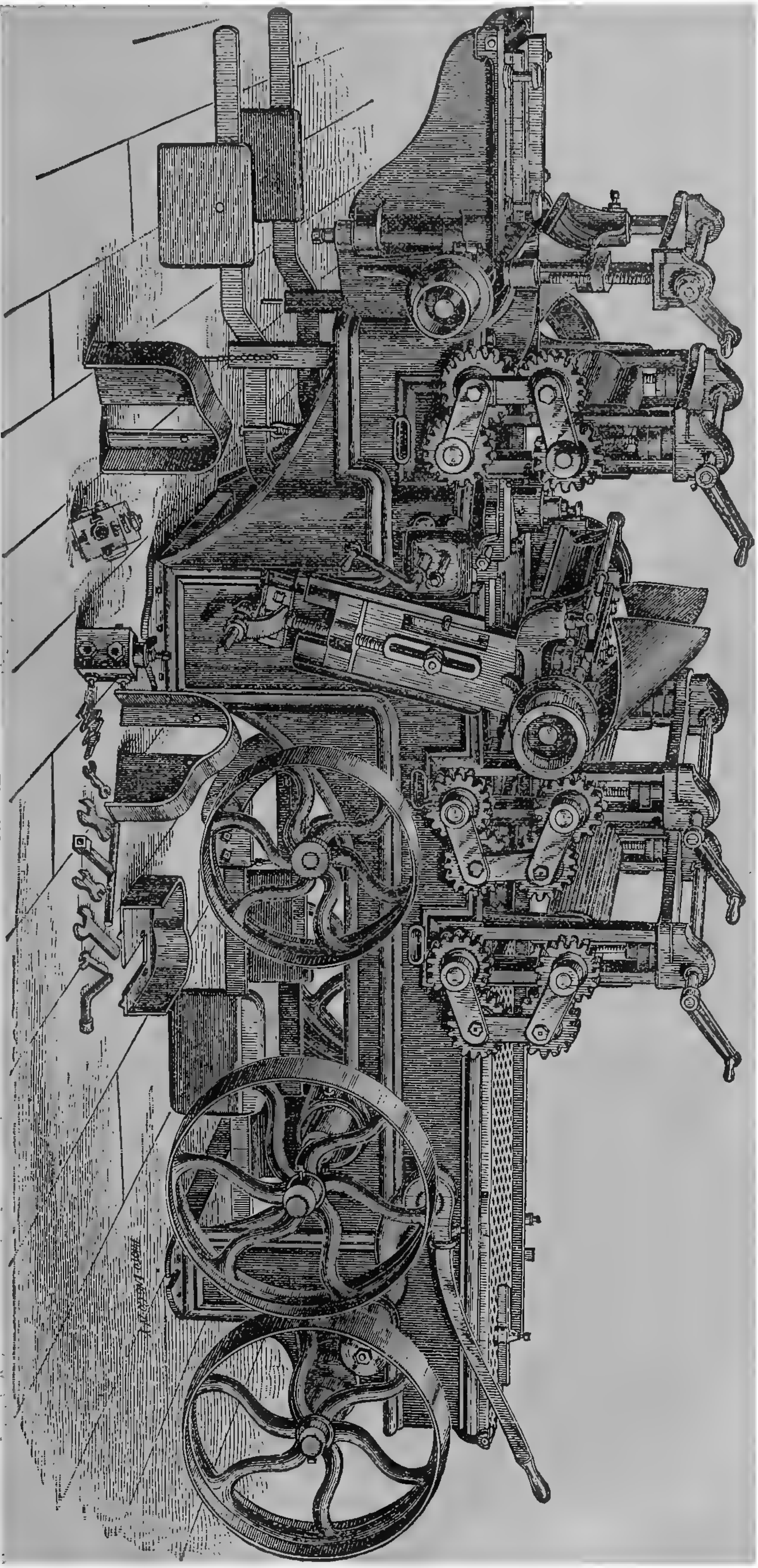


Fig. 422.

Many designers are content to depend upon the screws and the fit of the box-slides to keep the cylinder true and the boxes in line and free from bind; the best practice approves, however, the uniting of the boxes upon a yoke or cross-girt.

Fig. 421 shows the connection below the cylinder; Figs. 429 and 433 show the connection over it. Fig. 422 shows the type of arrangement in which the boxes are united through the screws only. The boxes are borne upon long oblique slides with wide bearing. The yoke below permits easy access to the cutters from above. Otherwise, the yoke must be high, as in Fig. 433, when it must be heavy in order to be stiff. A graduated scale indicates the thickness of the finished stock for each position of the cylinder. Babbitted boxes, with oil-cellars, are almost universal for these high-speeded spindles. In the best practice the babbitt-metal is bored out and scraped to a fit.

The larger types of tools which have been selected for illustration surface on the bottom as well as on the top. For this purpose a lower cylinder is used, driven so as to take a smoothing chip from the stock which passes over it. This lower cylinder in the majority of designs is put near the delivery end of the table. It is so placed that access to it shall be easy. Either the end of the table swings laterally out of the way (Fig. 420), or else the cylinder moves out straight sidewise upon ways (Fig. 434), or the whole roll and projecting table gear may swing. There is usually no adjustment necessary for this roll, and it always takes a standard cut. Its pressure-bars may be, therefore, of the simplest type, either fixed or with rubber springs. The lift of the cut is resisted by a short platen, adjustable by geared screws. In the designs of one builder (Fig. 434) the lower roll comes first in the series. There seems a certain logic in this arrangement, especially where the tool is a matcher as well as a planer. The

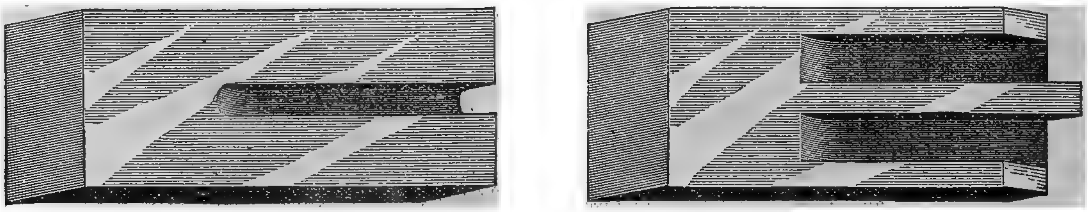


Fig. 423.

bottom of the stock is trued first, and from that faced surface as a basis the other cutters operate. Otherwise the first three cuts are made while the stock is guided by an unfinished and possibly untrue lower side. There is less objection to the older arrangement where the tool is a planer and surfacer only. The lower cylinder is most usually driven from a belt-wheel on the machine, which is turned by the friction of the belt to the upper cylinder (Fig. 420). The large wheel of the former pair acts as a kind of guide-pulley to the belt of the latter. The cylinders are driven from both ends in the best and largest types.

To secure largest output and income from a machine demands that it shall surface all four sides of rectangular lumber by once passing it through the machine. Therefore, beside the upper and lower cylinders (Fig. 422), there

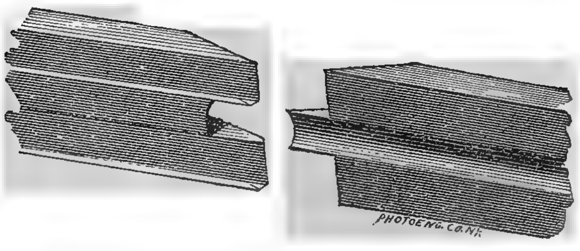


Fig. 424.

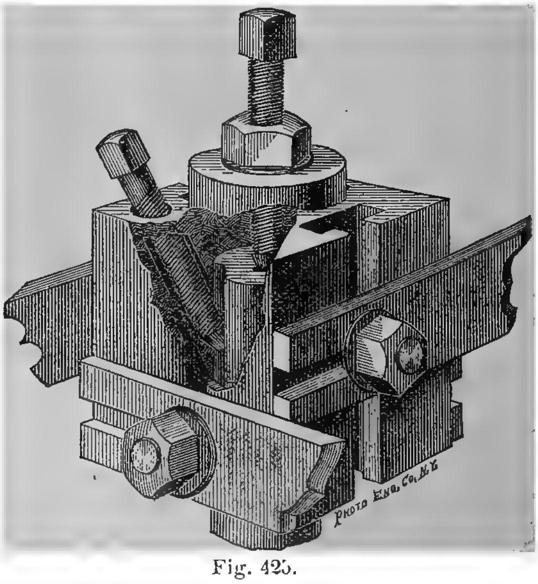


Fig. 425.

will be two vertical cutter-heads for operating on the vertical edges of the stock. These lie usually between the horizontal cylinders, and are driven by quarter-twist belts from a long drum or wide pulleys on the shaft at the extreme right. These belts are inside the bed, and some builders have special devices to keep them from overlapping. For board-machines there may be plain, narrow cutters, or there may be matching-cutters, to produce a tongue on

one side and a groove on the other. These matching-cutters may be milled from the solid (Fig. 423) or may be of the sectional type (Fig. 424). The general construction of an approved form of side head is shown by Fig. 425. It is here shown for molding-cutters, but any form of cutter may be used. The set-screw, which confines the head to the spindle, enters obliquely from the top, instead of radially from the side. The taper-point enters the spline and wedges the head fast without burring up the spindle.

Fig. 426 shows the more usual form, with radial screw. It is shown mounted upon a convenient device for insuring the proper adjustment of the cutters before the heads are put in place. When working upon thin boards, and especially upon brittle kiln-dried lumber or knotty and cross-grained stuff, the side heads are liable to split

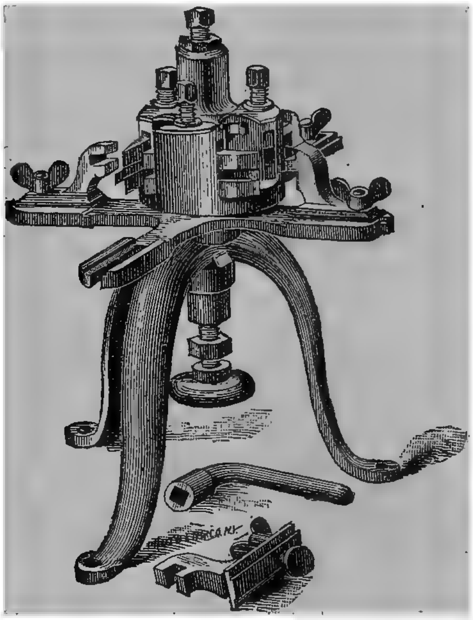


Fig. 426.

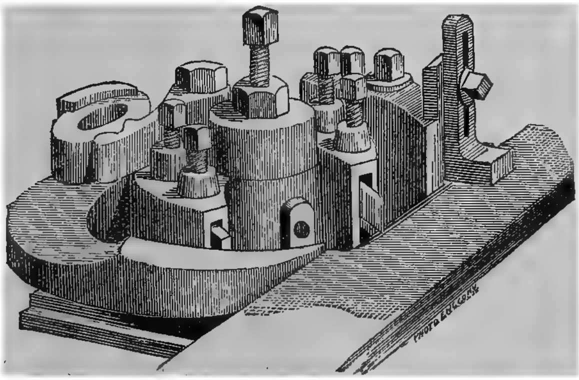


Fig. 427.

off slices or make a rough cut. To avoid this a side-pressure bar is used, consisting of a lever pressed by a spring in front of the cut, or in a patented design (Fig. 427) of a hinged chip-breaker, pressed against the side of the board exactly as the top pressure-bar of the same builders (Fig. 419). It is claimed that higher feeding-speed is possible with a device of this class. Both side heads act at once in planing- and matching-machines. It becomes

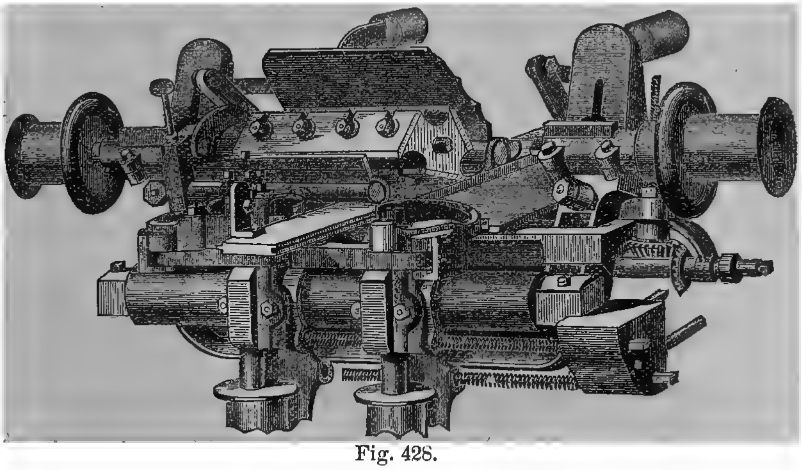


Fig. 428.

necessary to have the side heads adjustable laterally for standard widths of stock. This is effected usually by having the boxes for these side heads movable laterally. The boxes are upon slides, which are gibbed to transverse ways, and the slides may be set at any point by screws from the sides (Fig. 428). In some older designs the two heads were on one right and left screw, which moved both equally from the center. It is approved now to have each head controllable by a separate screw. The whole width of the planer-knives may be dulled before regrinding is necessary, and the bed does not wear so hollow in the middle. The lower boxes in the best practice have a special separate lateral adjustment to bring the spindles truly perpendicular or at a desired angle to the table, and there will be a slight vertical adjustment for exact setting of the cut. A steel tail-screw supports the foot of the spindle. When desirable to surface over the whole width of bed, the side heads in the design of Fig. 429 and many others may be lowered together out of the way by the rack and pinion device shown. The side heads themselves are made of gun-metal in the best practice.

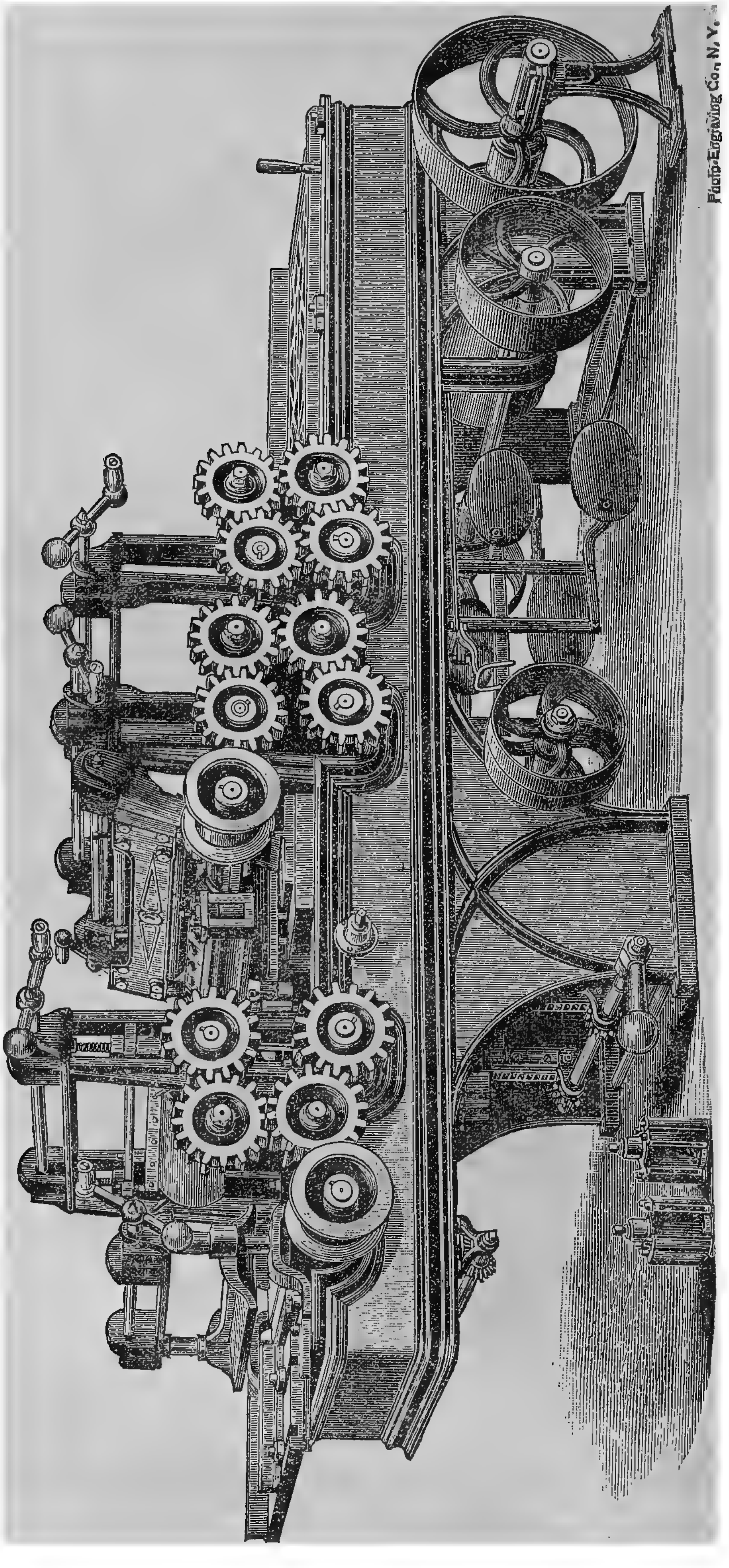


Fig. 429.

Fig. 430 shows the application of a small cutter-head at the extreme end of the machine, for beading or working up novelty siding. It will be driven from the main cylinder. This may be applied to any of the designs if called for.

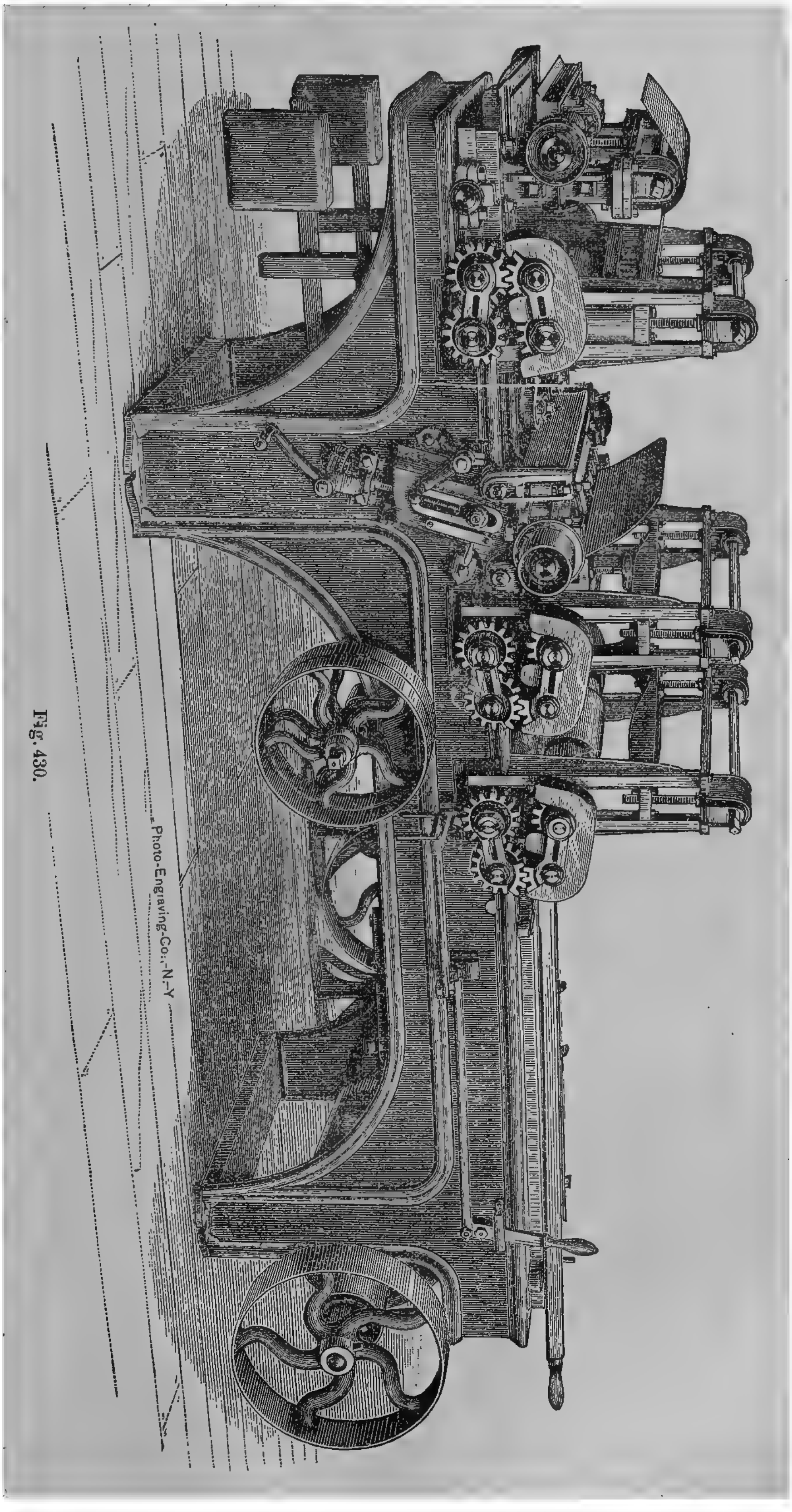


Fig. 430.

Since the action of the cutters is very forcible against the motion of the stock, it is necessary that the latter be fed in by power to the knives. In the tools of the class under discussion this feeding is done by driven rolls, which are weighted to grip the stock between them with sufficient pressure. The lower one is stationary, lying

just above the bed, while the upper one is adjustable for great variations of thickness by geared screws, and for slight incidental variations by the yielding of the weighted levers. The lower rolls (of which there may be two, four, or six) are geared together, the first one being driven by a belt from the cylinder usually, or else from the driving-shaft. The feed-belt is often made too long, so as to hang loose, and the feed is engaged by moving a lever which tightens the belt by guide-pulleys. There may be two belt speeds for feeding hard or soft lumber (Fig. 433), and they may have other special devices for reducing the speed or for engaging and disengaging. The cog-wheels which gear the lower rolls together are usually made large, and are on the right side of the machine. They are shielded in best practice. To permit the rise and fall of the top roll as thicknesses may vary is the object of the "expansion gearing", as it is called. In its original and simple form this consists in two idle wheels, which are upon floating pins linked together and to the upper and lower roll respectively (Fig. 422). The driving-motion from the lower geared roll passes through the train to the upper roll in whatever relative position the train may be, and thus a variation of 10 inches of capacity between the rolls is made attainable. The upper and lower roll of course turn in opposite directions. In its earlier forms these links for the gears bore on the axes of the rolls. Better practice fits them to the outside of the roll-boxes, and thus the wear on their fit is much reduced. They are also doubled in good practice to prevent the overhang of the intermediate studs. Most machines are geared at one end only. The machine of Fig. 420 carries the motion across by light shafts swung on the links (Fig. 431). These replace the studs of early designs. By this means a very strong and even feed is secured, and there is less danger of the cramping and wear of the gears. But a drawback to this feed-system by simple links is found in the supplementary motion imparted to the upper roll when it rises while revolving. Beside the driving speed it receives an additional rotation from the motion of the axes of the wheels around the centers to which they are linked. Whenever this occurs a variation in feed-speed occurs, and a wave or ripple is made in the work. To avoid this the design of Fig. 429 has the expansion in the upper pair of wheels only. The second wheel from the lower roll is stationary on a stud. The third wheel is upon a stud which has a horizontal motion in a slot, while the fourth wheel is linked to the third from the outside of the box. The first and the third and fourth are on different vertical planes, while the second has a very wide face.

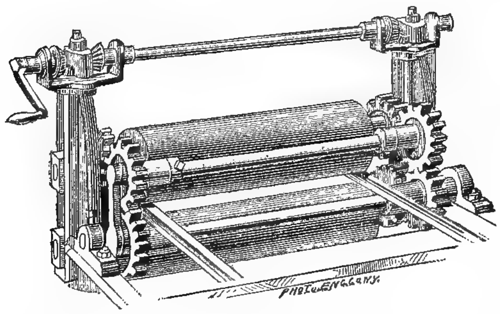


Fig. 431.

Fig. 430 shows what is called the Burleigh expansion-gear applied to the rolls, and Fig. 432 shows a similar device for compounding the motion of the third wheel. When the second wheel is lifted the curved slot gives a neutralizing motion to the train.

Fig. 433 illustrates a type of large planer and matcher in which the expansion-gear is partly inside the frame. The lower roll drives a gear upon an arbor, which passes through the framing, and an equal gear on the outside carries up the motion to the upper roll. The same design illustrates a usual type of guide for the stock that any tendency to "slew" may be prevented and to guide the material straight when the machine is used as a molder. There is also an illustration of a type of carriage for use upon grindstones to cause a straight edge on the knives.

In the types selected for illustration of present practice the bed is made of two sides, which are joined together by cross-girts. These sides may each have two or three legs. The cross-braces are bolted to the sides by bolts in reamed holes, and the true fit of the contact surfaces is secured by facing their bearing areas. The rude practice of bolting them together as they came from the sand is very generally condemned. The joints jarred loose, and the bed was not true. One builder, beside facing and bolting the braces, uses steel dowels for further stiffness and security. The most advanced practice tends toward consolidation of parts and casting in one piece as much as possible. Fig. 434 illustrates a departure in this direction. The four cylinders are attached to one central trough-casting, which bolts in place in a hollow of the bed. The lower surfacer acts first. By the system of expansion-gears in two planes the advantages are gained of the use of gears larger than the rolls. The weighting of the rolls is effected by a very neat mechanical device, by which no adjustment of the linkage and levers is required as the rolls are lifted to take in thicker stock. The adjustment also by hand does not need to overcome the feeding-weights, but the latter act immediately when any one roll rises separately. The rolls are lifted by worm and wheel combinations driven by hand-wheel or power. The worms are splined to their shaft, and their motion in one direction is resisted by a collar, while the bent levers connected to the weights press against their other ends. These bent levers hold each other in equilibrium when no pressure is on the rolls, or when they are lifted or lowered together. Should one roll be forced to rise by thicker lumber below it, its rise tends to turn its worm-wheel and to move the worm along like a rack. This rack-like motion is resisted by the weight and bent lever of that roll. The upper and lower cylinders are separately driven by a shaft at each end of the bed. The lower head can slide out upon ways, and the matcher heads have ample adjustment in all directions.

The chief feature of Fig. 435 consists in the use of cutter-heads with nine knives, instead of the usual three or four. The knives are of thin steel, with a cap. This divides the duty of cutting, and enables a high feeding-speed to be used. The standard speed for this machine is 150 feet per minute. The older practice approved from 20 to 50 feet, which is still all that some machines admit of. The feeding-rolls on this machine are large, of 9 inches in

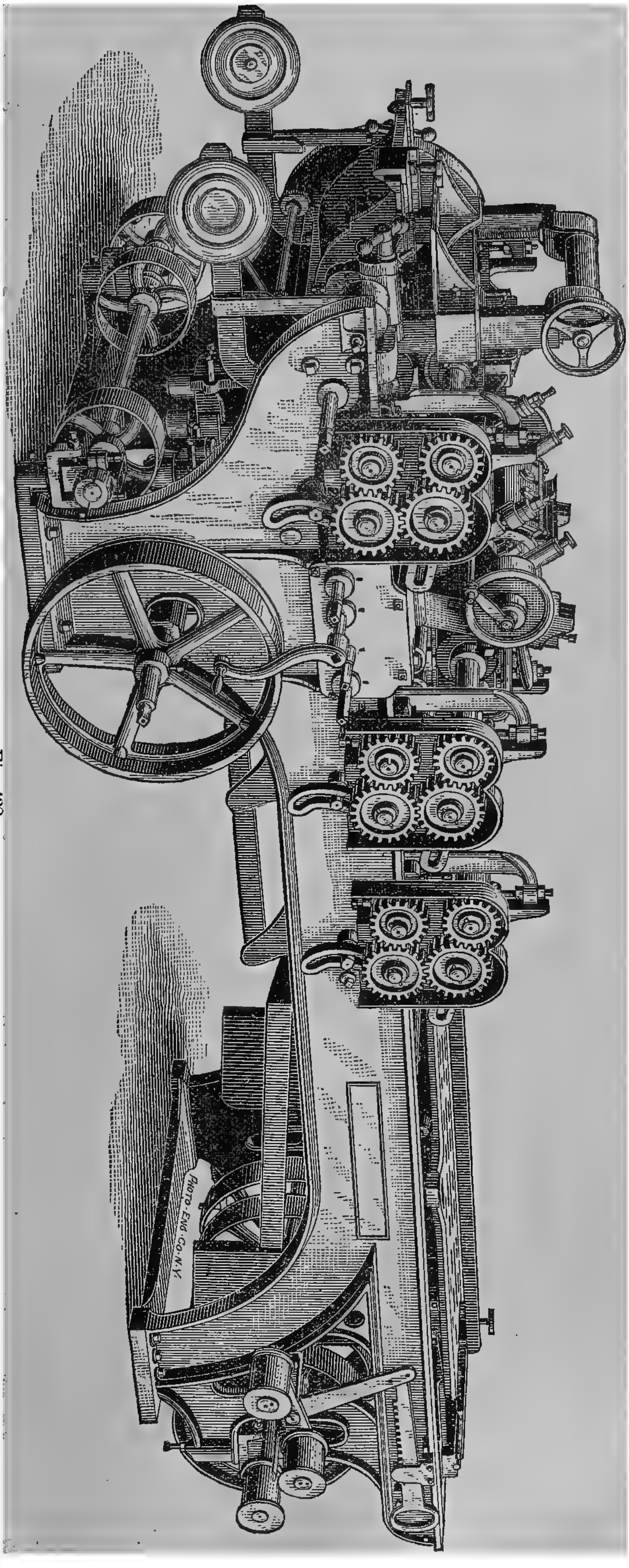


Fig. 432.

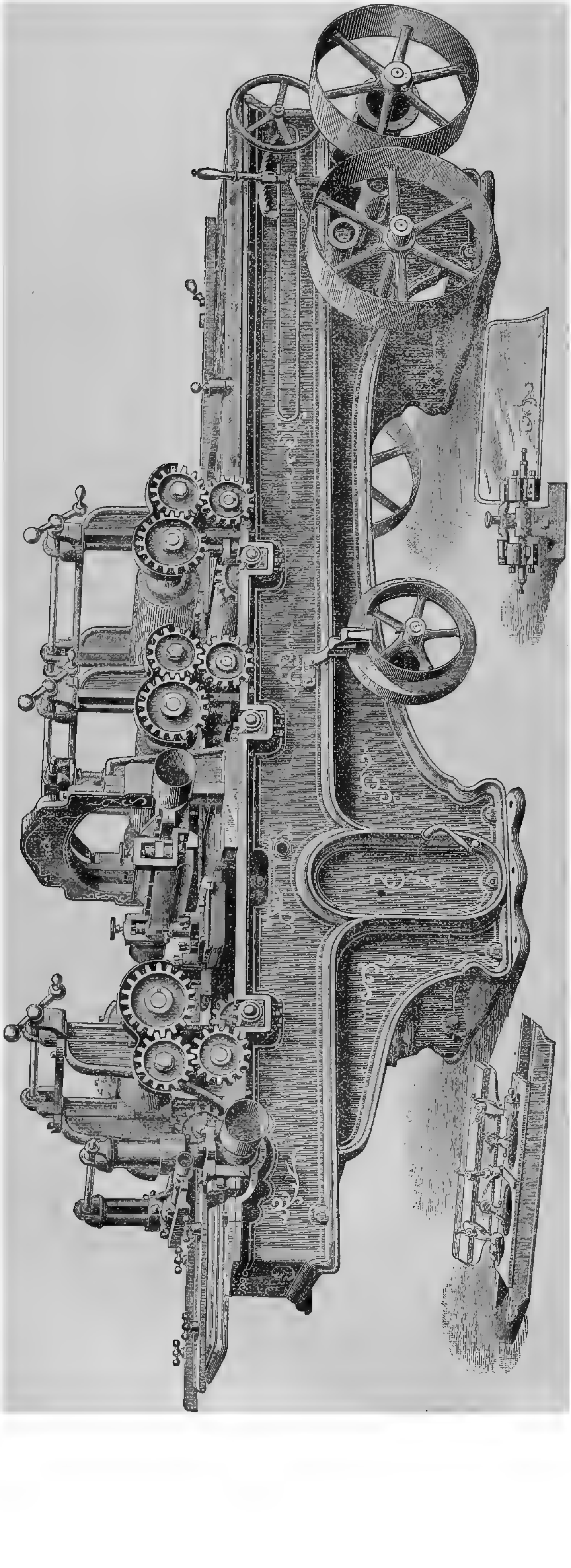


Fig. 433.

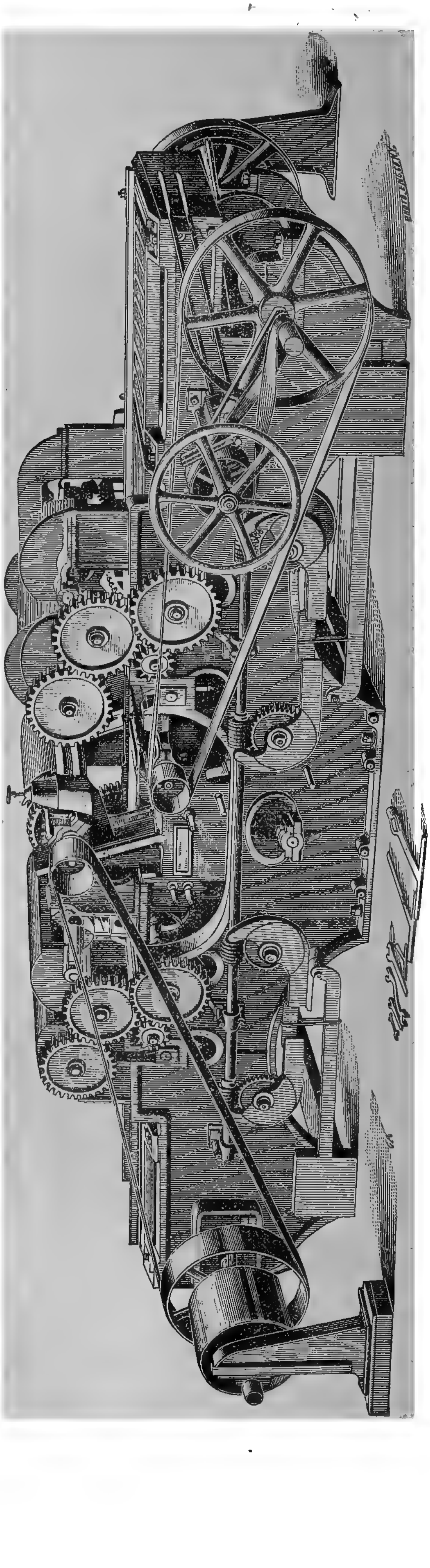


Fig. 434.

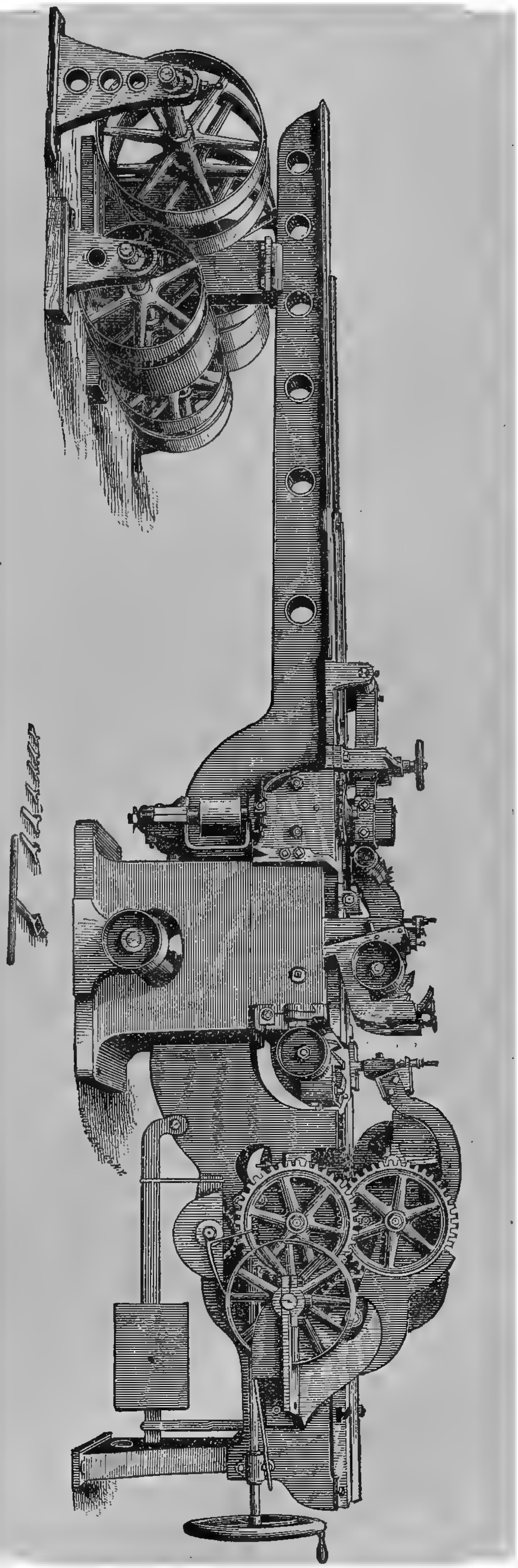


Fig. 435.

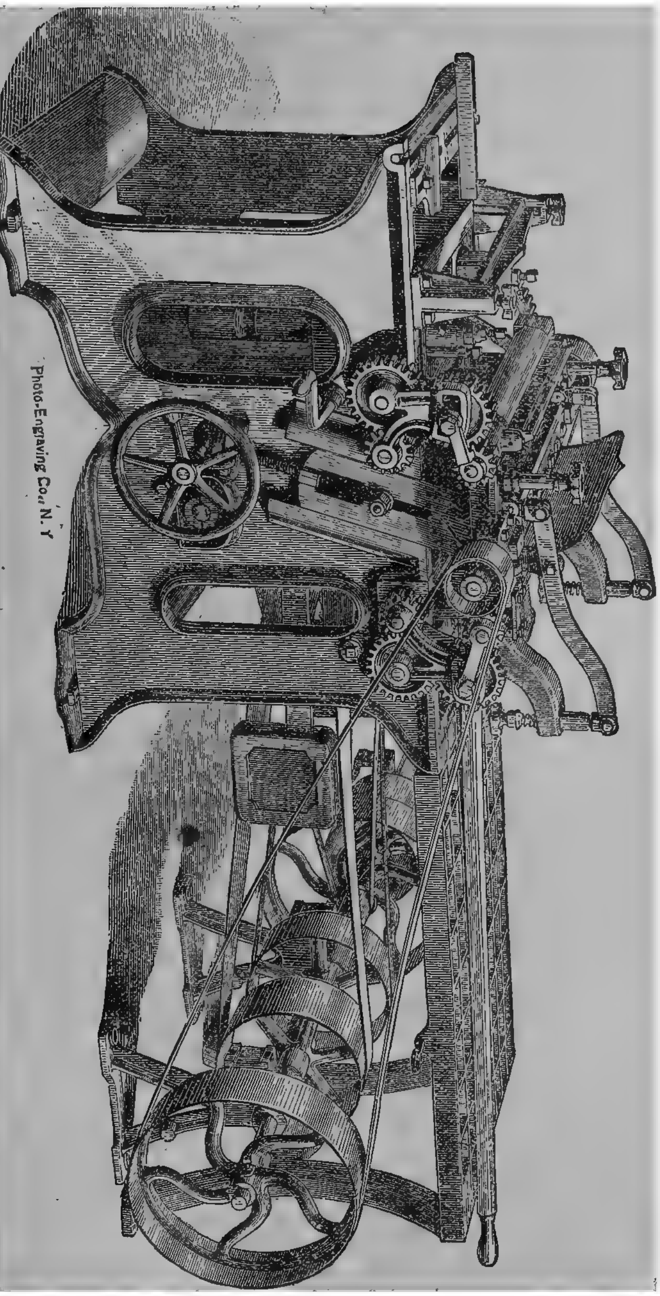


Fig. 436.

diameter, and the upper one is fluted, while the lower is plain. Fluted rolls are usually of small diameter, of 2 or $2\frac{1}{2}$ inches, in other designs, while a great many use all smooth rolls. One designer, driving the rolls from both ends, divides the rolls in the middle. This permits boards to be fed side by side, even though they may vary in thickness, and thus nearly doubles the output of a surfacing-machine. With solid rolls the thinner board will cease to be fed, because the thicker board has taken off the pressure from it. The rolls driven from one end, from difference in the leverages of the weights, will feed a board obliquely sometimes, which gives trouble at the matcher-heads.

The suppression of many parts of the larger machines selected as types is very usual. This gives rise to a series of simpler and cheaper machines, adapted for special classes of work and special financial conditions. Figs. 436 and 437 show two types of such machines. Fig. 436 is the older form, and shows an especial arrangement of expansion-links. In Fig. 437 the principle of one casting is illustrated. The feed-rolls are driven by worm-gear.

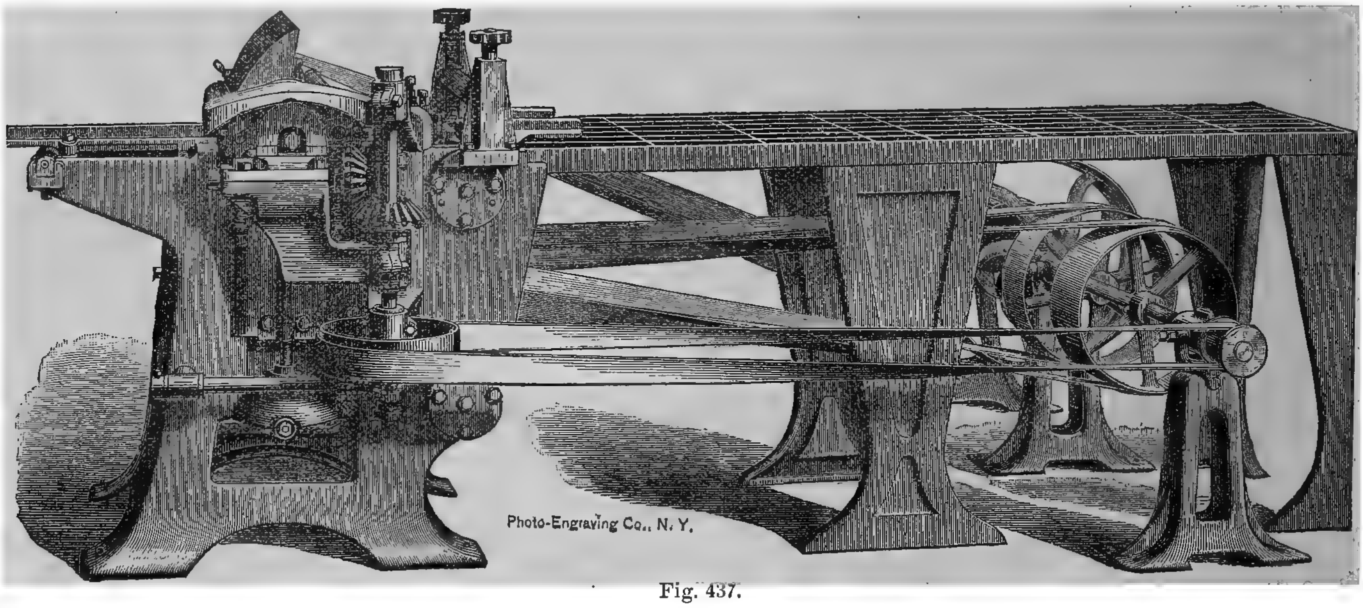


Fig. 437.

The knives in both are set with a retreat at one end of 1 inch in 24 inches, so as to give a dragging or shearing cut. This increases the smoothness of the surface in some woods. They require no further detailed allusion. The machines discussed are the successors of those made under the original Woodworth patents, which ran from 1828 to 1856. These patents were for the combination of rotary cutters and holding-down rolls which are required in all designs. The first machines were built with wood frames. Iron frames were introduced about 1850. The decision with regard to the Woodbury pressure-bar claims as further released this type of machinery. The improvements in the later designs over the earlier have been in the direction of greater strength and stiffness of bed and frame, more ample bearing and wearing surfaces being provided, and steel is more largely applied. The capacities of the machine have been enlarged. The feed-rolls will expand for lumber from one-fourth of an inch to 10 inches. Timber, 8 by 8 inches, can be faced on all four sides in new machines for such work as that for which the elevated railways are calling in the cities. The output of the machine has been enormously increased. Records are accessible of 55,000 feet of $1\frac{1}{4}$-inch lumber planed on two sides in eight and a half hours. The lumber was from 8 to 11 inches wide. Ten thousand feet of lumber of similar width and 1 inch thick has been planed on one side in one and a half hours. It is claimed for the machine of Fig. 435 that it will surface 40,000 feet on four sides in ten hours, if not more, on a trial. These are great advances on the performance of earlier days, and may be taken as indicative of the rapid progress which has made possible such an increase in productiveness.

§ 43.

ROLL-FEED SURFACERS.

To meet a want for a machine which should be rapidly adjustable in miscellaneous shops the roll-feed planers, with lowering bed, have been introduced. The bearings of the upper cutters are fixed, and the rolls have only rubber adjustment, if any at all. The variation for thickness is obtained by lifting and lowering the whole bed or table by a crank or hand-wheel. The separate adjustment of the series of rolls is entirely avoided, the machine becomes much shorter and more compact, and a stiffness and solidity is obtained for the upper cutters which has commended the system very widely.

Fig. 438 illustrates a double surfacer and matcher of this kind. The whole bed is guided by long ways in the center, and is raised and lowered by screws geared from the hand-wheel. The lower rolls drive the upper through expansion-gear, and a tightener takes up slack from the under cutter. The matcher-heads adjust themselves with the table.

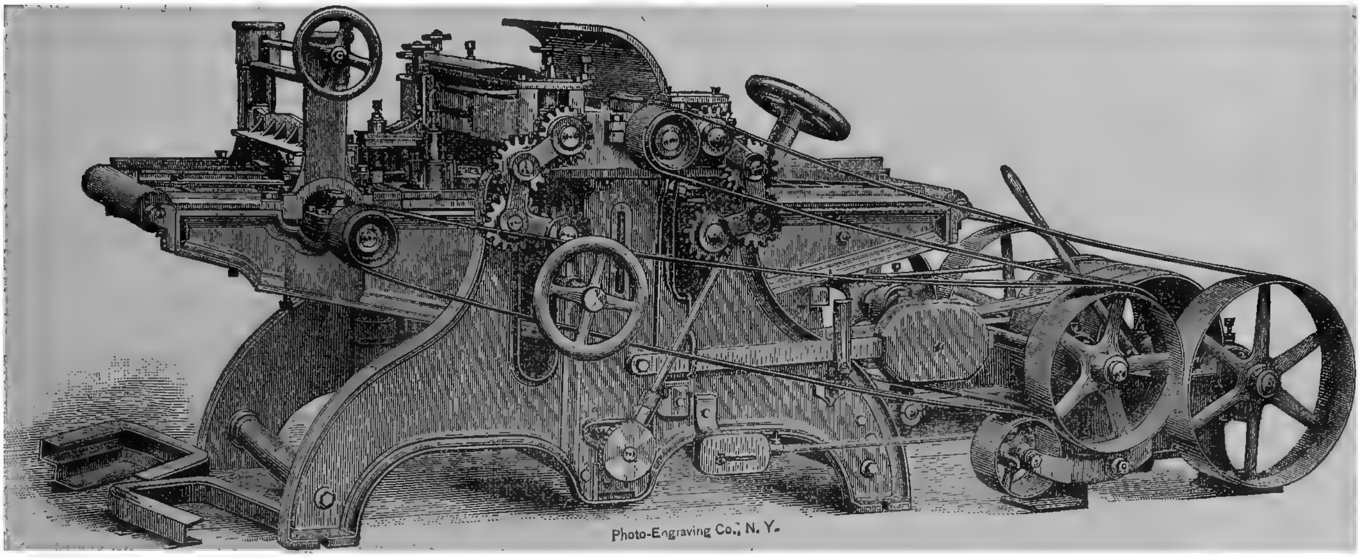


Fig. 438.

Fig. 439 illustrates a machine with both cutter-cylinders belted from one belt with tightener. The bed and all the feed-works give an adjustment for thicknesses between one-sixteenth of an inch and 3 inches. There are six rolls geared together expansively, the feeding-out roll carrying the stuff completely through. It swings out of the way to permit access to lower head. There are three changes on the cone-pulley of the feed-shaft.

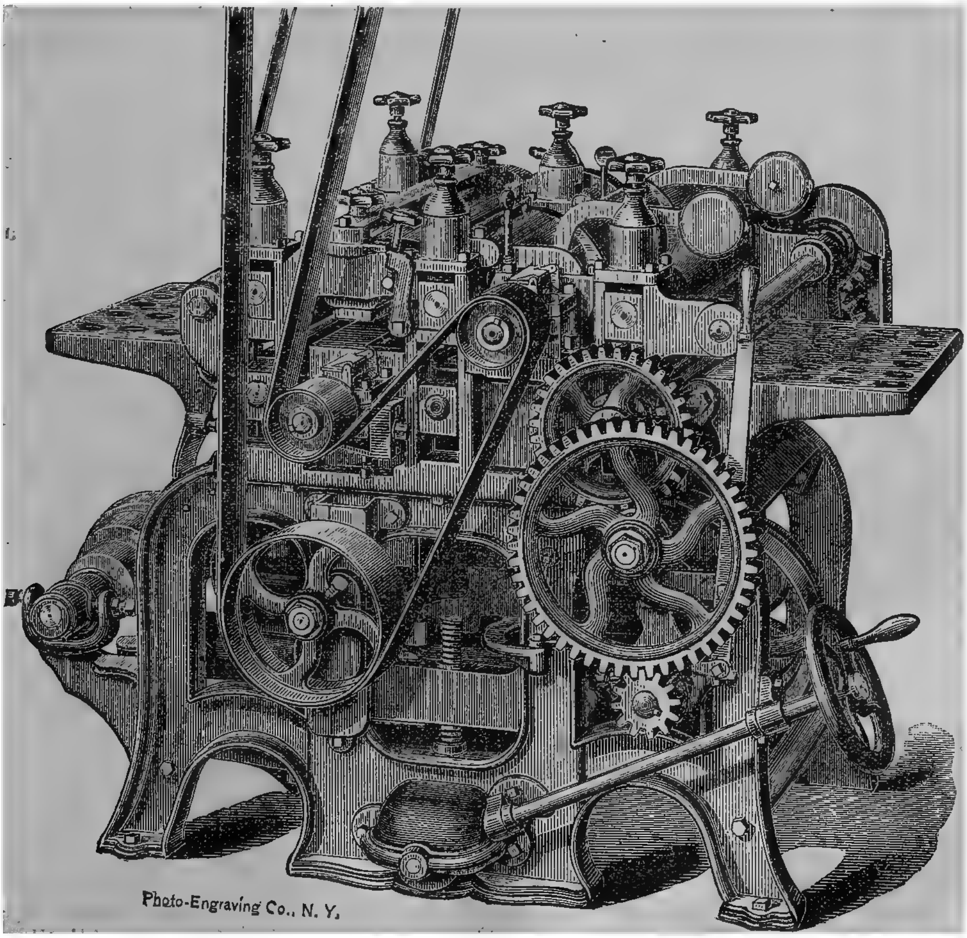


Fig. 439.

Fig. 440 shows a type of machine for upper surfacing and matching. After the long table has been set, the farther end may be clamped from swaying. It is raised with the central part by having its screw geared to the others by bevel-gears. There are four feed-rolls, and the counter-shaft is held on the lower extension of the machine. The feed-gear is engaged by tightening the loose belt.

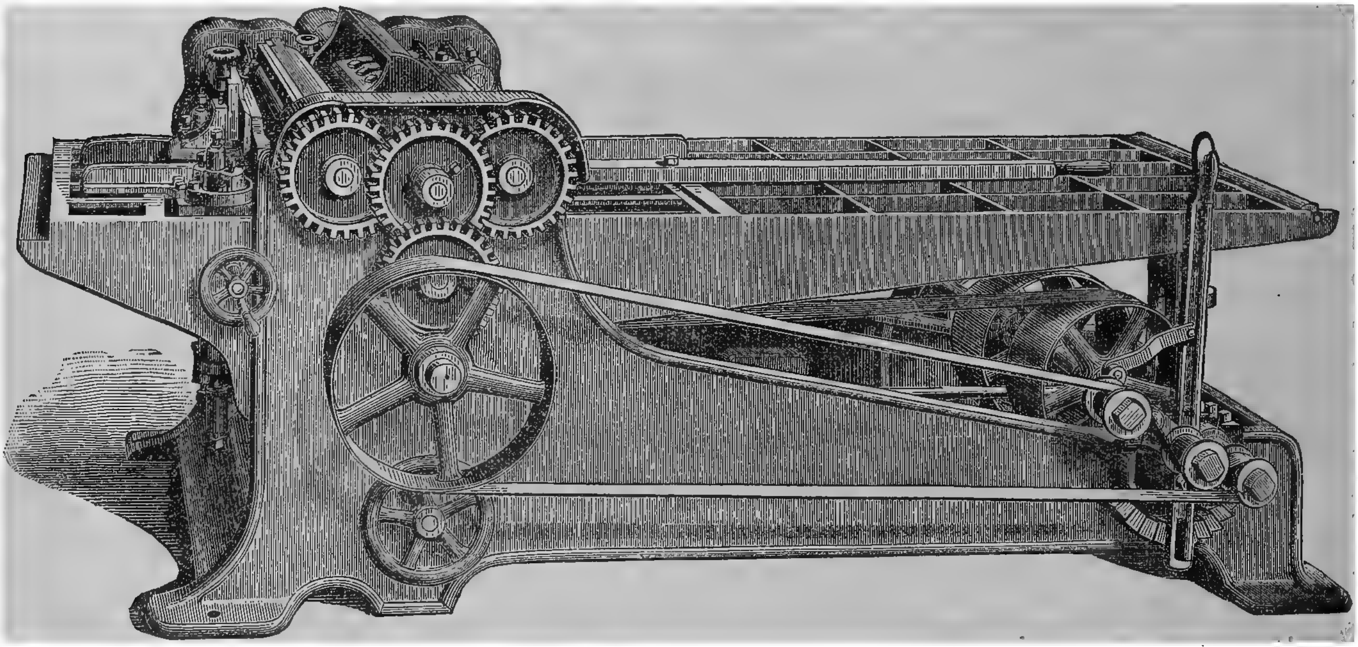


Fig. 440.

Fig. 441 shows a machine of excellent construction. The bed rises and falls by inclined planes, worked by a screw from the hand-wheel. One revolution of the wheel lifts the table one-eighth of an inch. The machine has capacity from one-sixteenth of an inch to $6\frac{1}{2}$ inches. The feed-rolls are driven by heavy gearing, which may be arrested instantly, and which permit two changes of speed. So powerful is the feed that half an inch may be taken off at one cut. The pressure-bars move in grooves concentric with the cutter-head, so that pieces of 3 inches in length may be planed without clipping the ends. The journal-boxes are self-oiling by a strip of felt put in a groove in the babbitt. The journals are long ($7\frac{3}{4}$ inches), and are belted at each end. Such machines will take in lumber up to 48 inches wide.

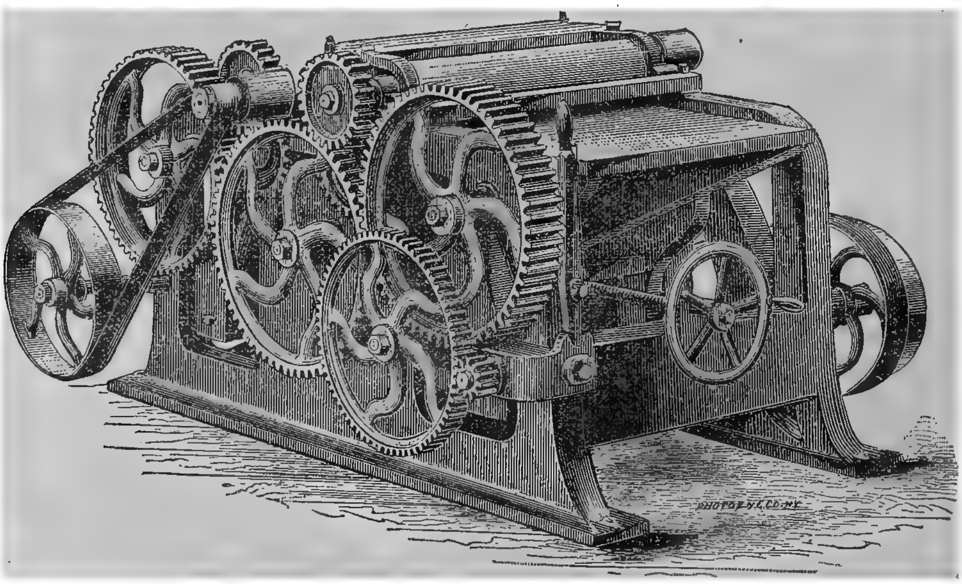


Fig. 441.

Figs. 442 and 443 show a very prevalent type of single surfacer, which is often called a "pony" planer. One shows rubber springs for both upper rolls, and the other has weights for the front one. The feed is controlled by tightening the belt. The adjustment for thickness is made by geared screws.

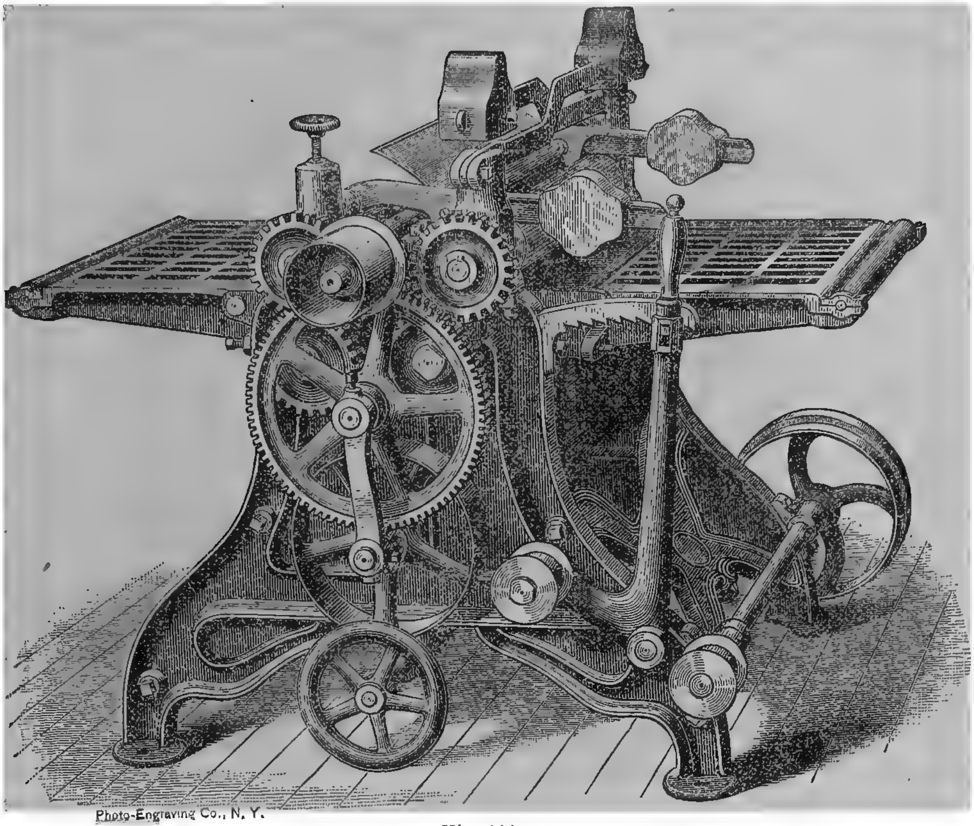


Fig. 442.

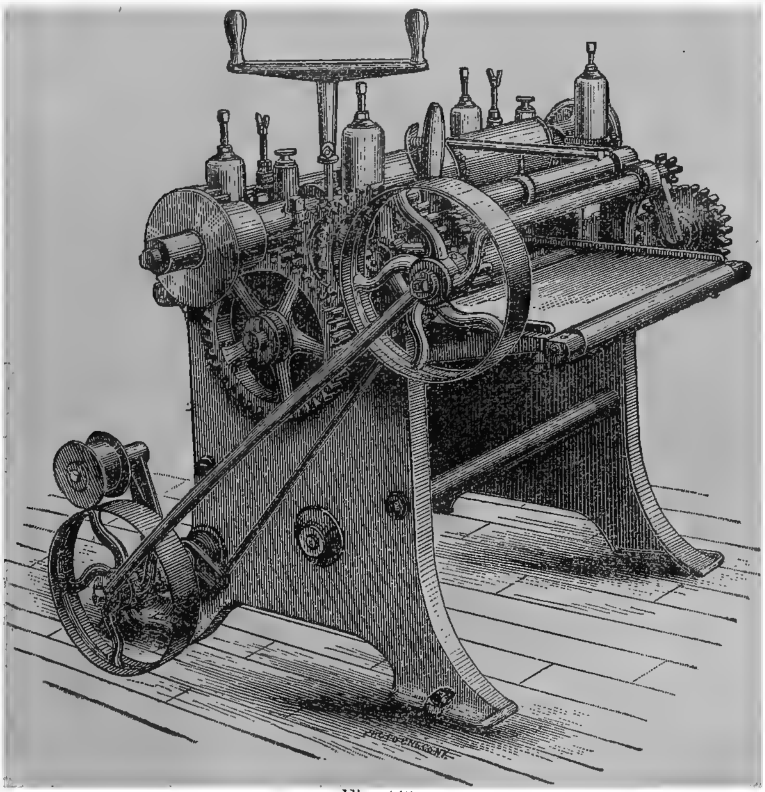


Fig. 443.

Fig. 444 illustrates a very compact pony planer, or panel-planer for finer and more exact work of short length. The bed adjusts for lumber up to 4 inches thickness by the hand-wheel. The rolls are driven by a neat application of the brush-wheel friction. The position of the driver is controlled by a lever, with a latch locking into a sector.

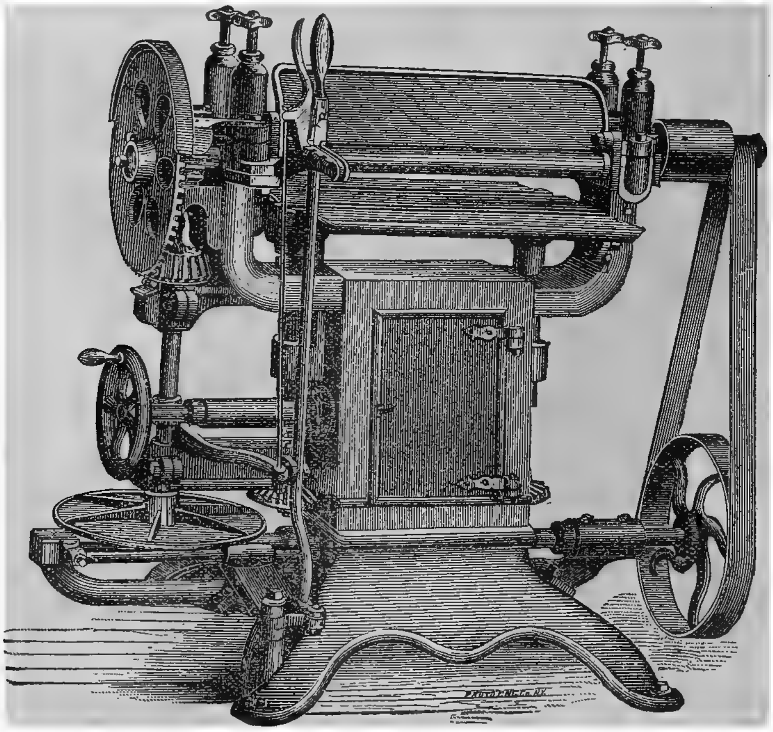


Fig. 444.

An ingenious release of the friction when the feed is to be shifted or reversed adds further to the excellence of the device. The opening of the latch lifts the face-wheel, and the weight of the latter acts as a latch-spring. A variation of feed between 20 and 40 feet is thus possible. For certain purposes, it is desirable that the cutter should act

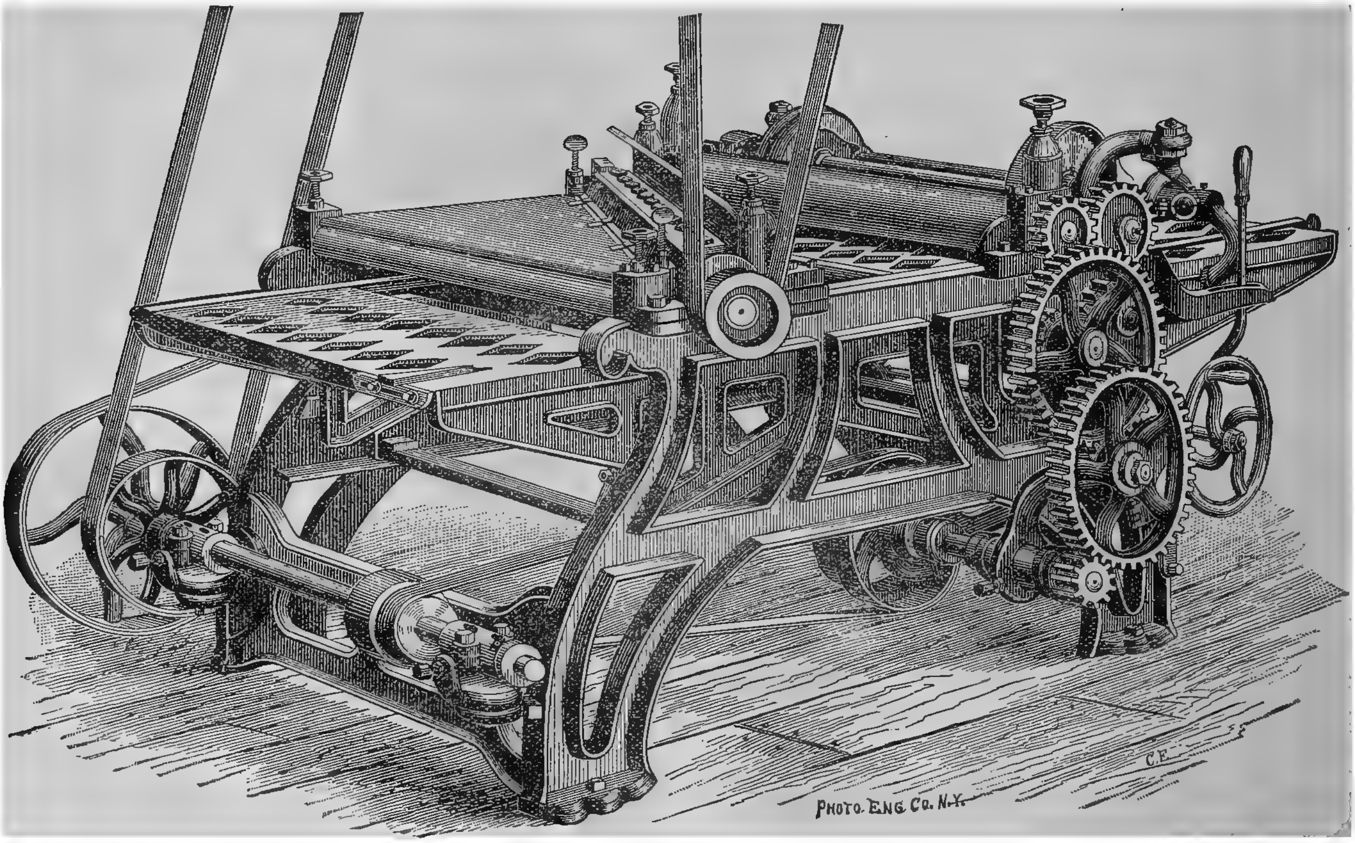


Fig. 445.

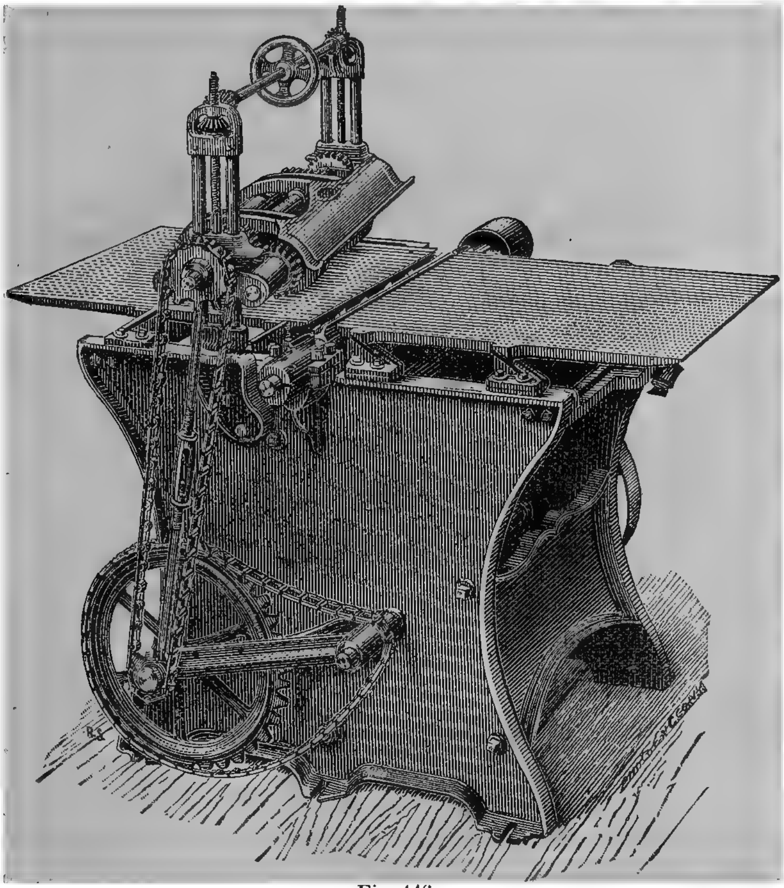


Fig. 446.

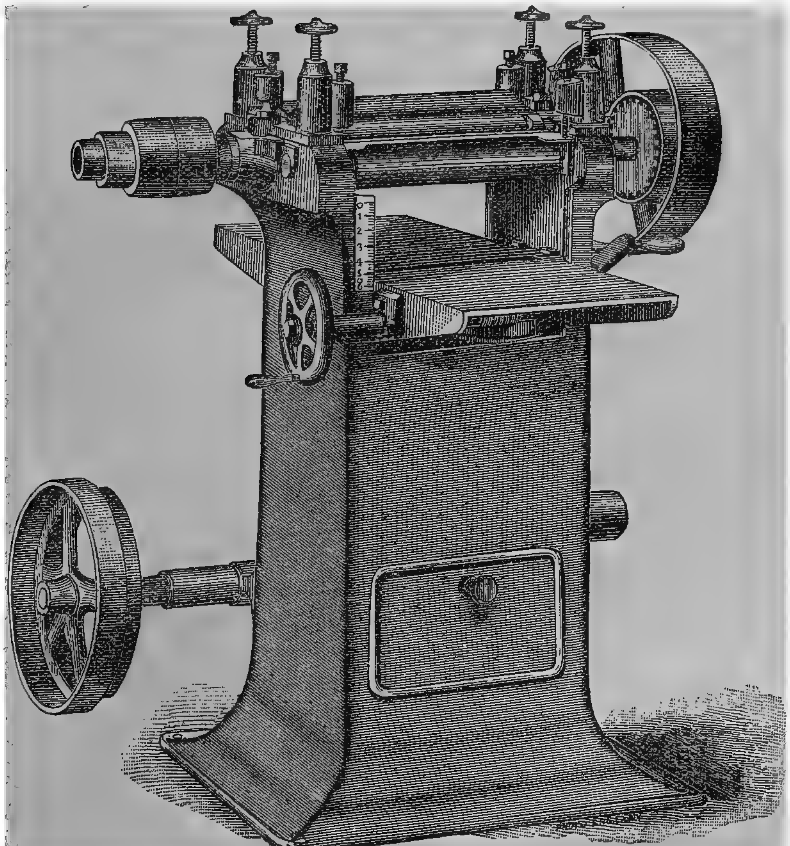


Fig. 447.

diagonally upon the stock presented to it. This is especially desirable for work made up of lumber with the grains running both ways, as in doors, shutters, and paneled work. Fig. 445 illustrates such a machine, with a capacity for 500 doors per day, working one door of 7 feet in length on both sides per minute. Tenons, wedges, etc., are cut off by adjustable saws at the work end, and the table adjusts for thickness by inclined planes. To counteract the variation in thickness of rails and muntins the pressure-bars have independent adjustments, that they may bear equally with requisite pressure on all parts of the surface. There are two changes of feed, disengaged at will.

Fig. 446 shows a diagonal planer, with feed by gearing-chain, using rubber bands on the rolls. It may also be used as a straight buzz planer. The great simplicity of Fig. 447 results from the arrangement for moving the table. The table is borne by a large round pillar, which fits inside the standard. A screw of gentle pitch is cut on the pillar, and a nut which fits it is revolved by a worm on the hand-wheel shaft. The screw on the pillar lifts and lowers, and the tangent gearing acts as a clamp. Pony planers or surfacers of this class are very useful and popular for small, short work, and for sized pieces. Long work would overhang too far to permit accuracy.

§ 44.

ENDLESS-BED OR TRAVELING-BED PLANERS—FARRAR OR LAG-BED PLANERS.

By the above names is known a large class of machines adapted for heavy and rapid surfacing. They appear in two general forms.

Fig. 448 shows the type in which the cutter-head and bars rise and fall, while the bed has no vertical adjustment.

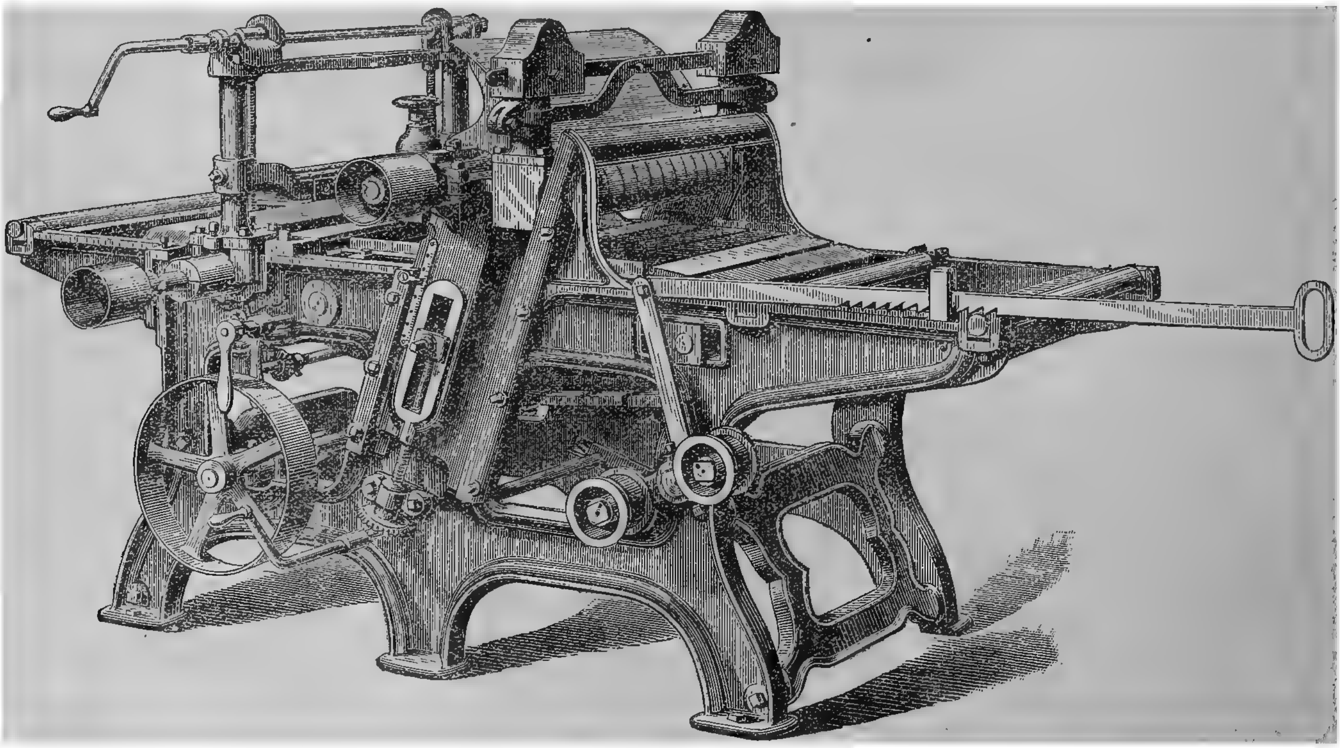


Fig. 448.

Fig. 449 illustrates the type with fixed head and adjustable bed. The latter type is the prevalent one, on account of the rigidity and stiffness which the fixed boxes give to the upper cylinder. The other system offers advantages when double surfacing is to be done. The stock is fed to the cutters by the motion of the bed on which it rests. This bed is made of slats or lags, linked together into an endless belt sidewise and driven by sprocket or polygonal wheels within the bight. These lags are supported upon longitudinal ways beneath the cutters. There are either two, three, or four of these ways. Against the three-way system the objection is urged of excessive wear on the middle one. There are two at the ends of the lags and one midway between them. The bulk of the pressure on the lumber is borne by this third way, since the stuff is instinctively presented centrally. On wide lumber the flexure of the thin lags will cause the surface to taper to one side after the machine has been in service for some time, or produce uneven thickness when the machine is changed from narrow to wide stock. To prevent this objection the two-way system is preferred by some excellent builders.

Fig. 449 shows a detail of the lags. They are cast with a deep web, to prevent flexure between the ways, and the latter are brought nearer together by linking the lags outside of them. Against the two-way system is the objection that it is possible for the lags to be lifted against the cutters by a pressure at their ends. This cannot happen, however, when the two ways are at the extreme ends.

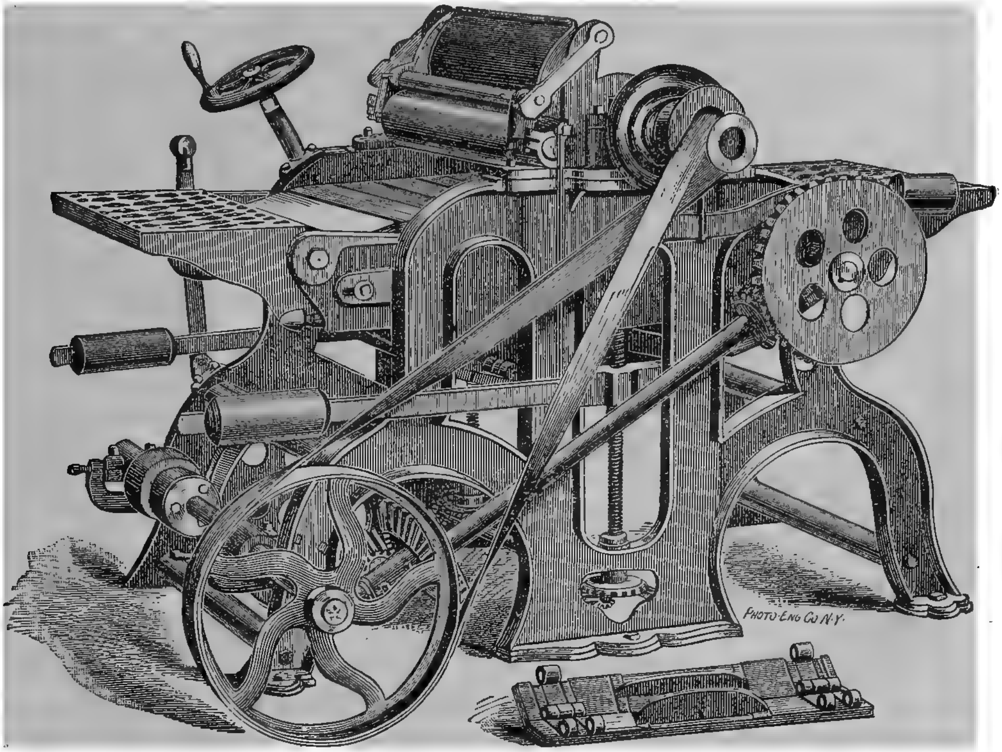


Fig. 449.

Fig. 450 illustrates a machine with four ways to counteract this latter danger and distribute the wear. The ways are provided with oil-cellars, which lubricate the lags as they pass over saturated fibrous material. The lower

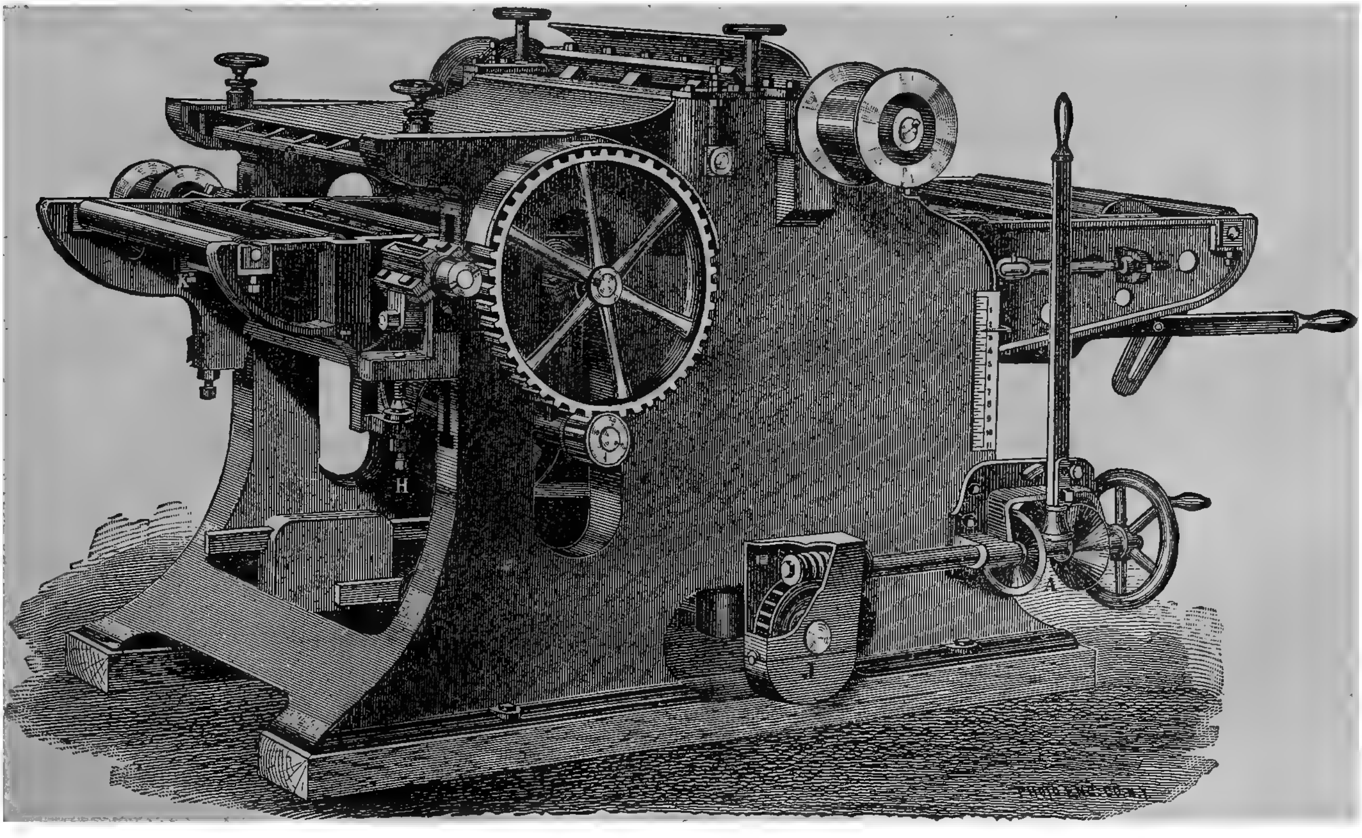


Fig. 450.

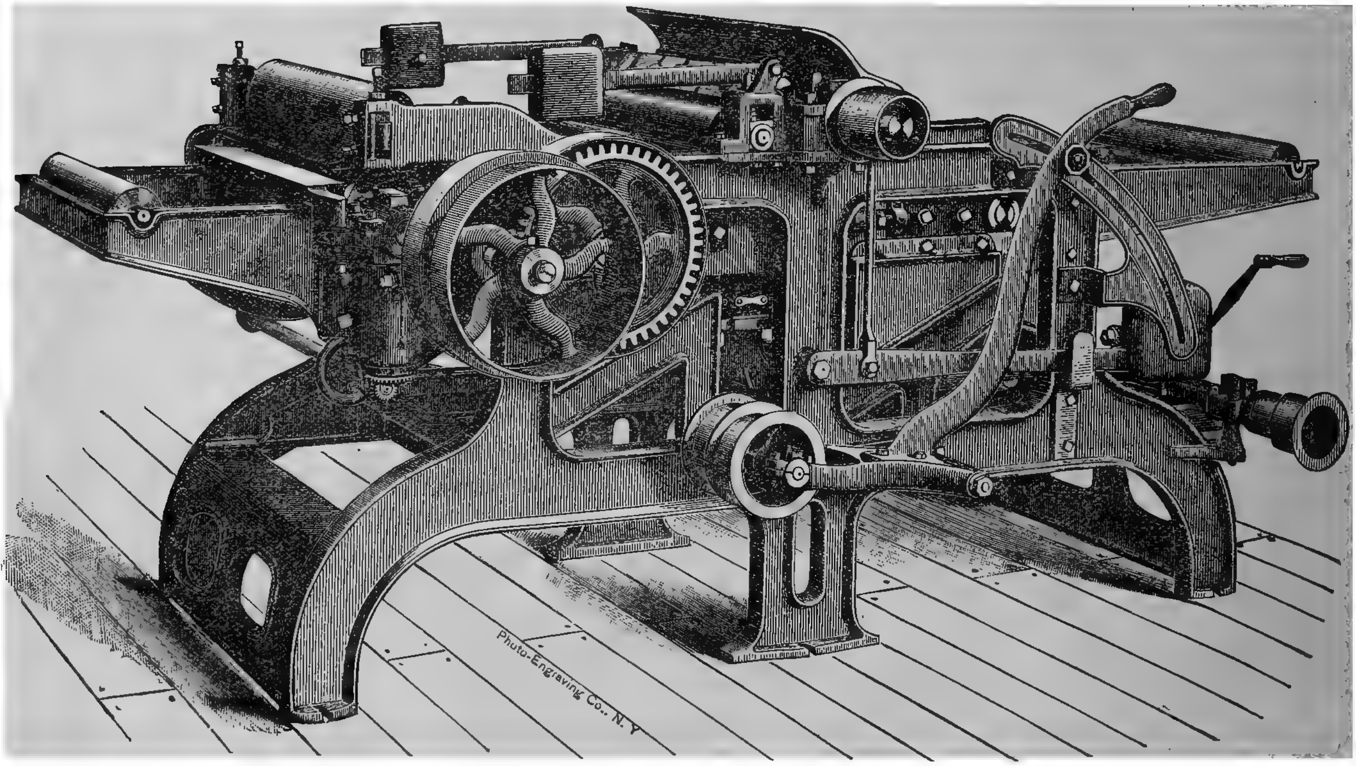


Fig. 451.

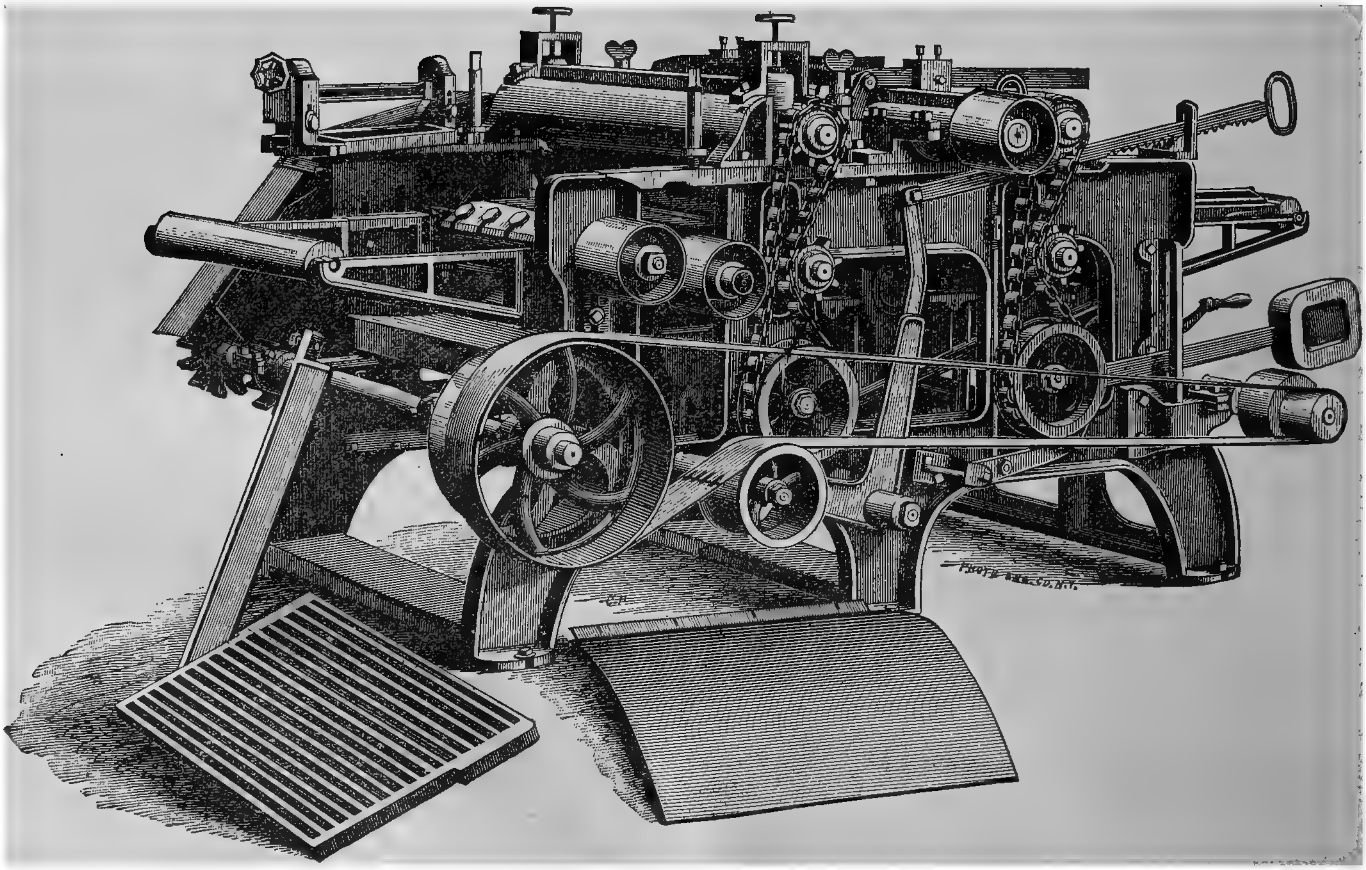


Fig. 452.

bight hangs slack and the sag can be controlled by a lateral adjustment of the bearings of the idle drum. The lags are linked together by flat links in commoner practice like a gearing-chain. The alternate single links are on the lags.

Fig. 449 in the detail shows the lags hinged together by ½-inch wrought-iron pintles, instead of riveted links. Special profiles have to be given to the lag-corners to prevent them from kicking up or chipping the lumber as they

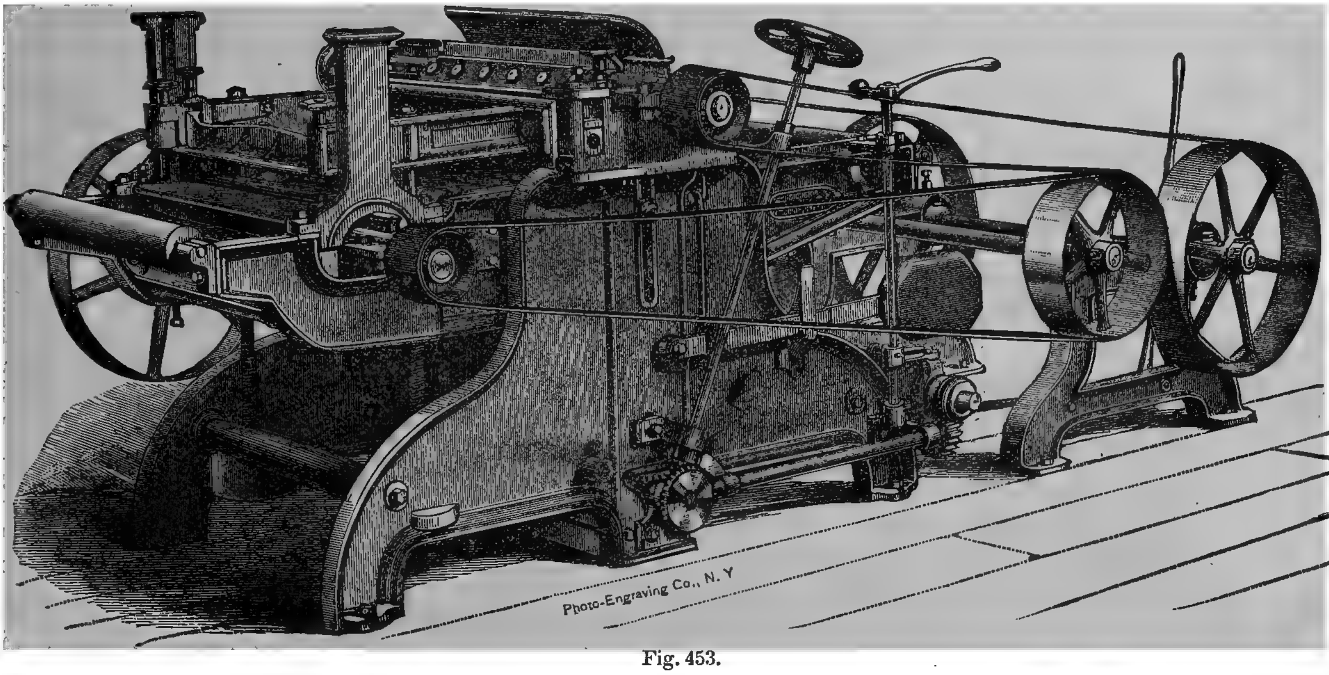


Fig. 453.

pass from the circular drum to the tangent ways. The driving-drum is always at the back of the machine. Fig. 449 shows it driven by bevel-wheels from a friction-shaft with two speeds. Fig. 451 shows the more usual system by belt-tightener, clamped to a sector. The upper pressure is found to increase the resistance to the feed if left plain. In best practice it becomes a roll, and the chip-breaker is separate. The latter comes close enough to the cut to be effective, but does not press so heavily upon the stock. These pressure-rolls are not usually driven, but are turned by friction of the stock.

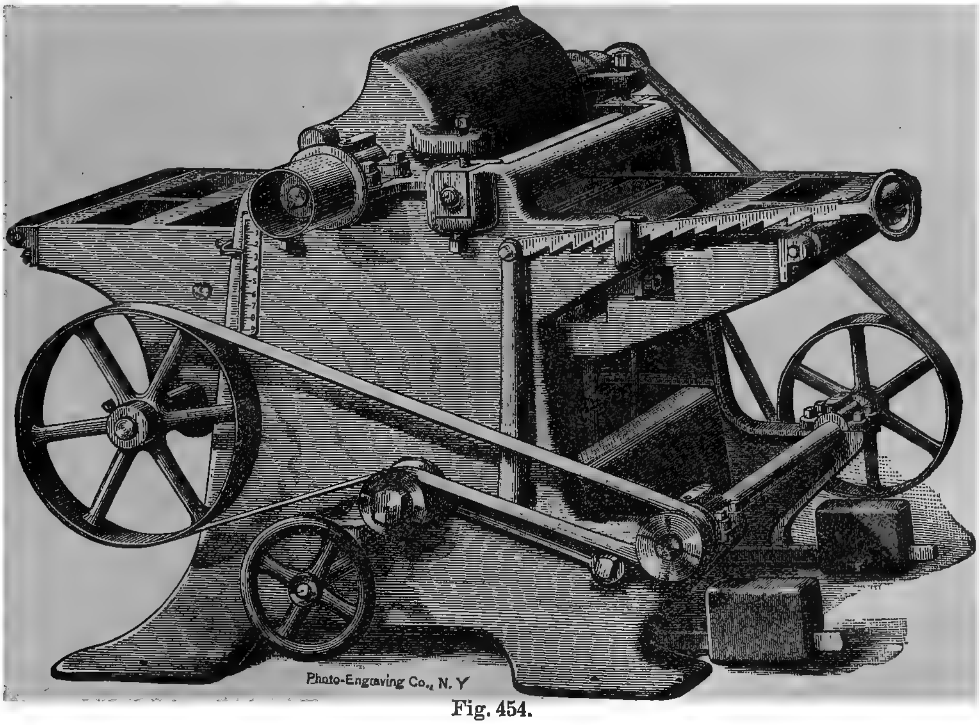


Fig. 454.

Fig. 452 shows the upper rolls driven by slack-gearing chain. The same builder uses this same device for his expansion gear on fixed-bed Woodworth planers instead of the usual links. The cut illustrates a double surfacer,

and shows the convenient method for freeing the lower head for inspection and sharpening. The grating of the part beyond the cutter-cylinder lifts away and the pressure-table swings out of the way. An objection to the double surfacers with adjusting bed is the difficulty of unsteadiness in the under head. This must rise and fall with the table, and the loose fit of the latter to permit motion magnifies the vibrations. In the design of Fig. 450 the boxes of the lower head may be clamped to the sides of the frame, making the lower head as firm as the upper. There are adjusting-screws to bring the two cylinders parallel, and hand-screws adjust the platen over the lower. The table is raised or lowered by screws geared together or else by inclines. It is guided and kept horizontal by

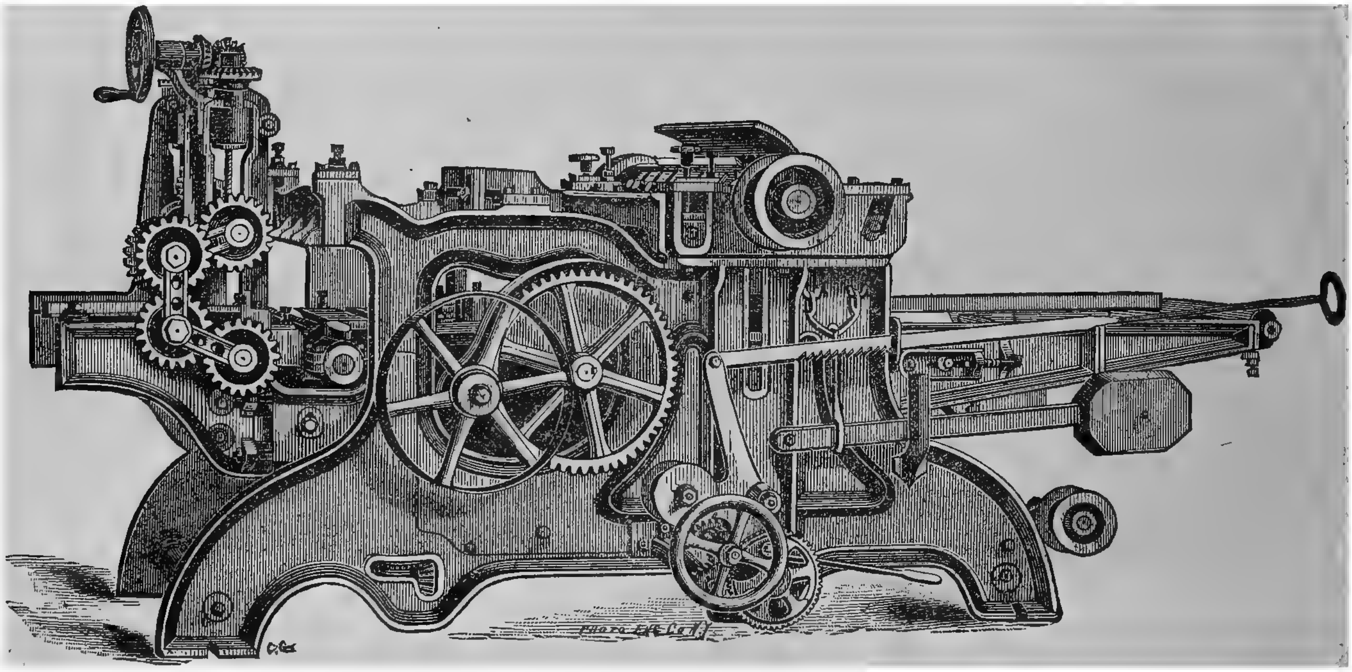


Fig. 455.

dovetail slides. Fig. 453 shows the screws geared from the power-shaft by short right-and-left worms. These can be engaged at will with the worm-wheel by the vertical shaft. Fig. 450 has the worm-shaft driven by friction from the central bevel-cone. There is also a hand-wheel adjustment in all cases. The types illustrated show the diversities of practice with respect to the resistance of the pressure-bars or rolls. Fig. 448 has the weighted levers cross each other, with a special integrating device at the center. Fig. 451 has the standard weighted levers, and some of the others show the adjustable rubber spring.

Fig. 454 shows the use of the shaving-guard as supplemental to the roll. An extension of the bonnet comes down close to the cutter-head and acts as a chip-breaker. The front roll lifts the bar and prevents the stock from catching on its corner. The other features of the designs will be visible from the cuts.

The endless-bed planers are not very extensively built as matchers also.

Figs. 455 and 456 illustrate very large machines of this type for dressing car- or bridge-sills, and similar 10-inch lumber. The system of Fig. 456 is not without its advantages in these heavy machines, since the weight of table and attachments does not have to be overcome. Extra feeding-out rolls are made necessary, in order to free the matcher-heads, which have to be beyond the end of the traveling bed. The cheaper and smaller type of Fig. 457 and the surfacers of a little larger size are by far in the majority. The endless-bed planer, as a type, is especially adapted for fast work, which may be permitted to be rough. It can do very smooth work when properly built and slowly handled. It has done splendid service for lumber which was wet or icy, upon which the Woodworth rolls might slip or fail to catch. The weight of the work favors the feed, instead of resisting it. It has a speed of feed of about 60 feet per minute, and in its "pony" form is very popular, even to the displacement of the other forms in certain classes of work.

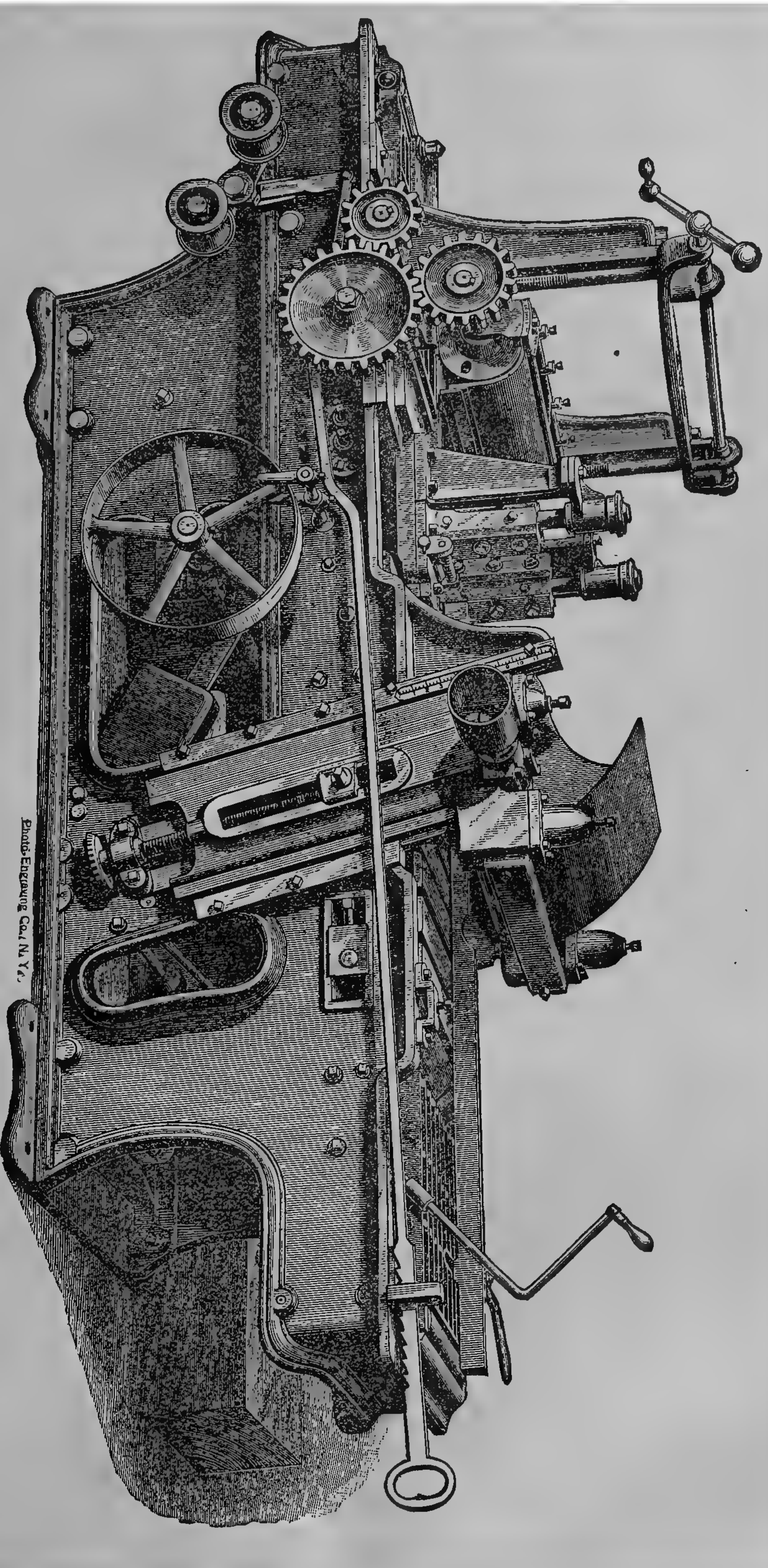


Fig. 456.

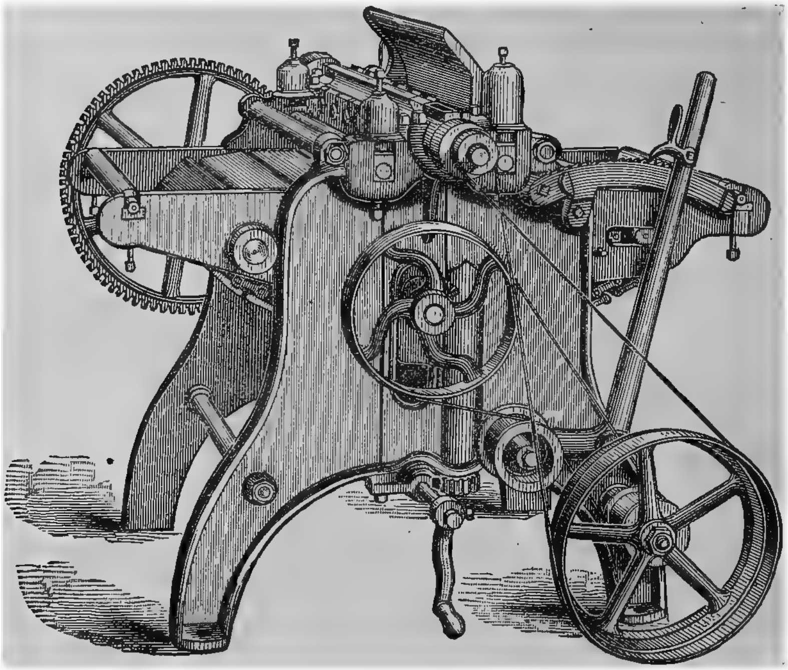


Fig. 457.

§ 45.

BUZZ-PLANERS—HAND-PLANERS—HAND-JOINTERS.

In the tools of this class the wood is held by hand and presented to the cutting-edges. They are adapted for surfacing and for jointing all kinds of small and joinery work, and effect a notable saving of time in comparison with hand-labor. One of the chief special problems they present is to permit an increase of depth of cut, without unduly increasing the opening at the cutter-head.

Fig. 458 (see next page) illustrates the general appearance of these tools and a special device for securing a close fit around the cutter-head. The table is made in two halves, with the edge of the cutters just protruding between them. The work is pressed upon the tables by hand, and is guided by the fence. This will incline for chamfers and bevels. The two tables are swung above the pairs of short links, and the screws at each end lift and lower the tables as the links are made perpendicular or inclined. The edges nearest the cutter describe a curve which is nearly an arc round the center of its axis.

Fig. 459 shows a hollow-base jointer, where a parallel link device secures close approach to the arcs of the knives. Two hand-wheels are necessary, because the back table should always be in line with the top of the

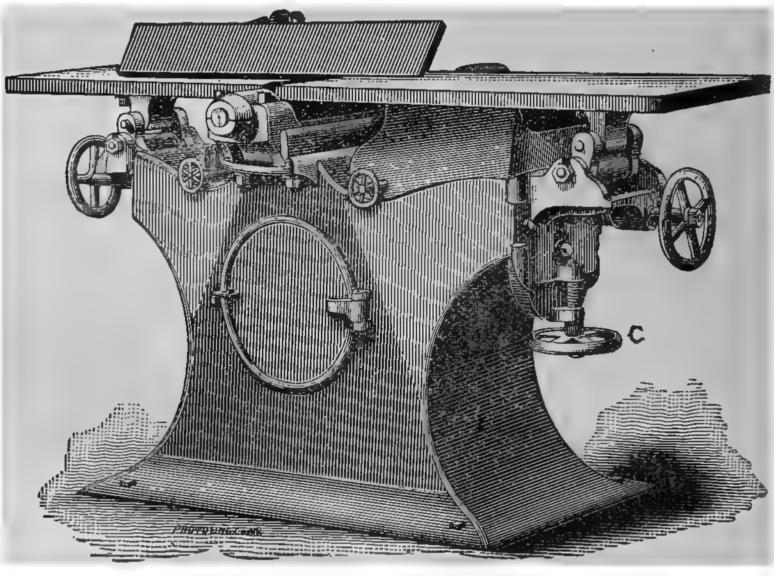


Fig. 459.

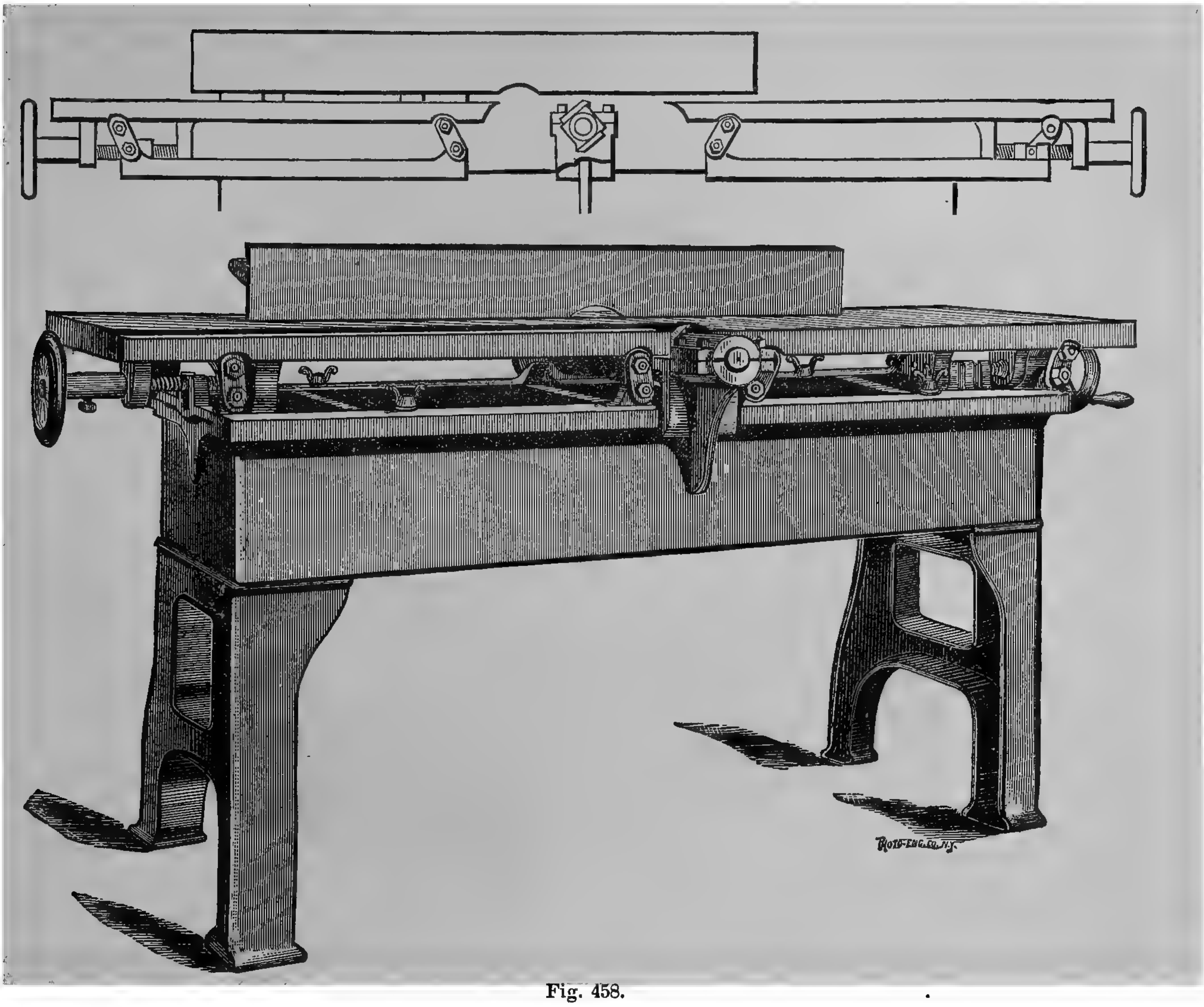


Fig. 458.

cutters. The depth of cut is gauged by the front table only. In order to make hollow or spring joints for gluing the front table is lowered by the hand-wheel C. When joints are planed hollow, the clamping of the glue-joint need be in the middle only.

Fig. 460 shows a similar design by the same builders, where the cutter-head stands at an angle with the direction of the feed of the stock. It is called a diagonal jointer. The shearing cut adapts the machine for cross-

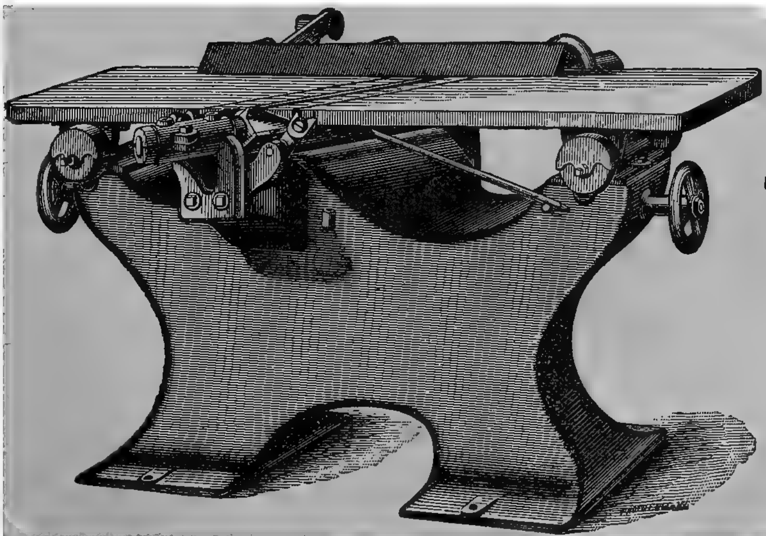


Fig. 460.

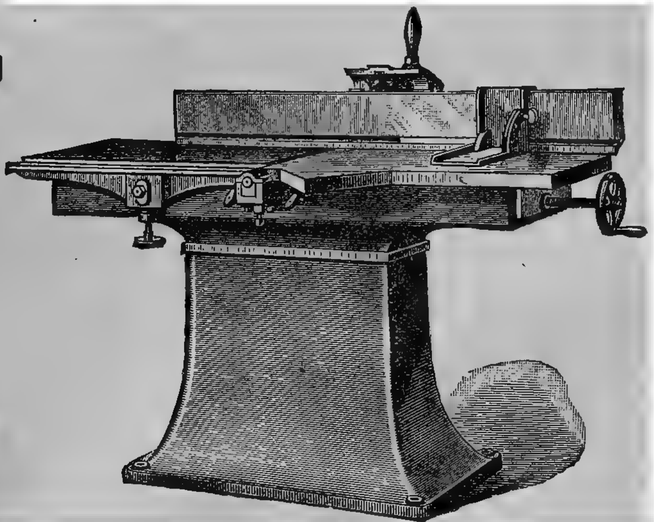


Fig. 461.

grained and curly lumber, and gives a smooth surface. In the planer of Fig. 461 the fence may be set at 45° to the vertical plane through the cutter-cylinder, and thus transform the straight jointer into a diagonal one. In this tool the danger to the hands of the operator when working on short pieces is overcome by the use of a finger guard. The tables rest on inclined planes, and their lips are faced with steel. The cutter-cylinder has three bearings, to secure freedom from spring. Some of the other forms of buzz-planer permit a horizontal tilt to the tables.

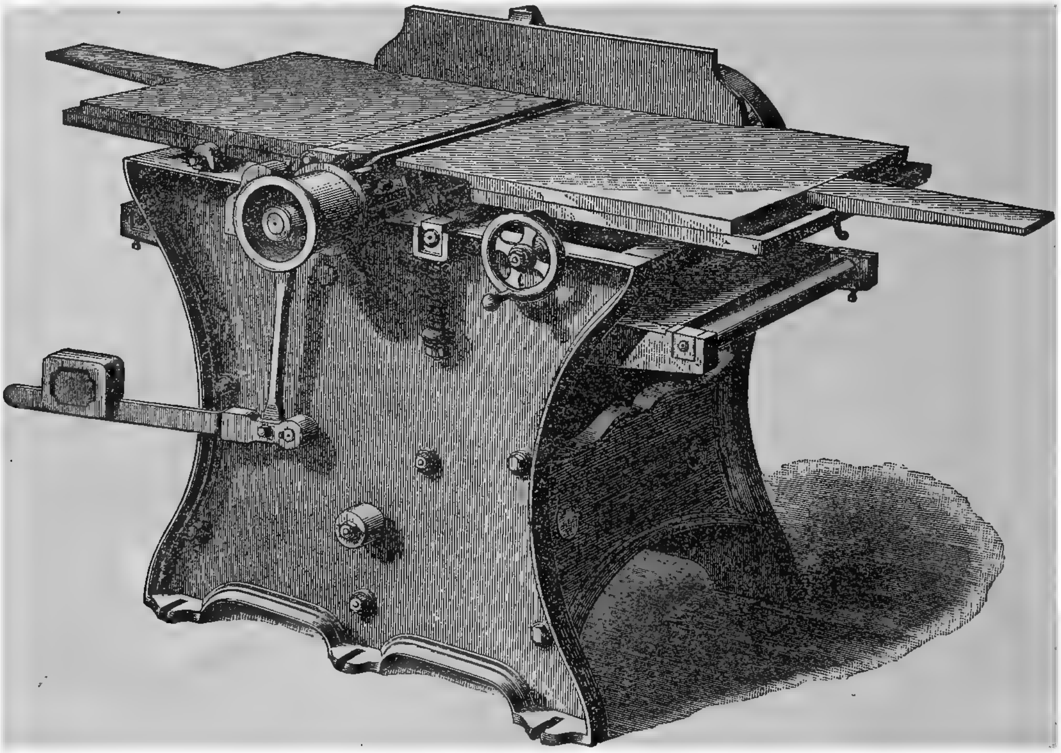


Fig. 462.

Fig. 462 shows a machine arranged to use the upper side of the cutter-head as a buzz-planer, and also the lower side as a pony surfacer. There are feeding-rolls driven by gearing-chain for the roll-feed over the lower table. The lower table rises and falls by screws, and Fig. 463 shows the expansion-gear for lower rolls. The front

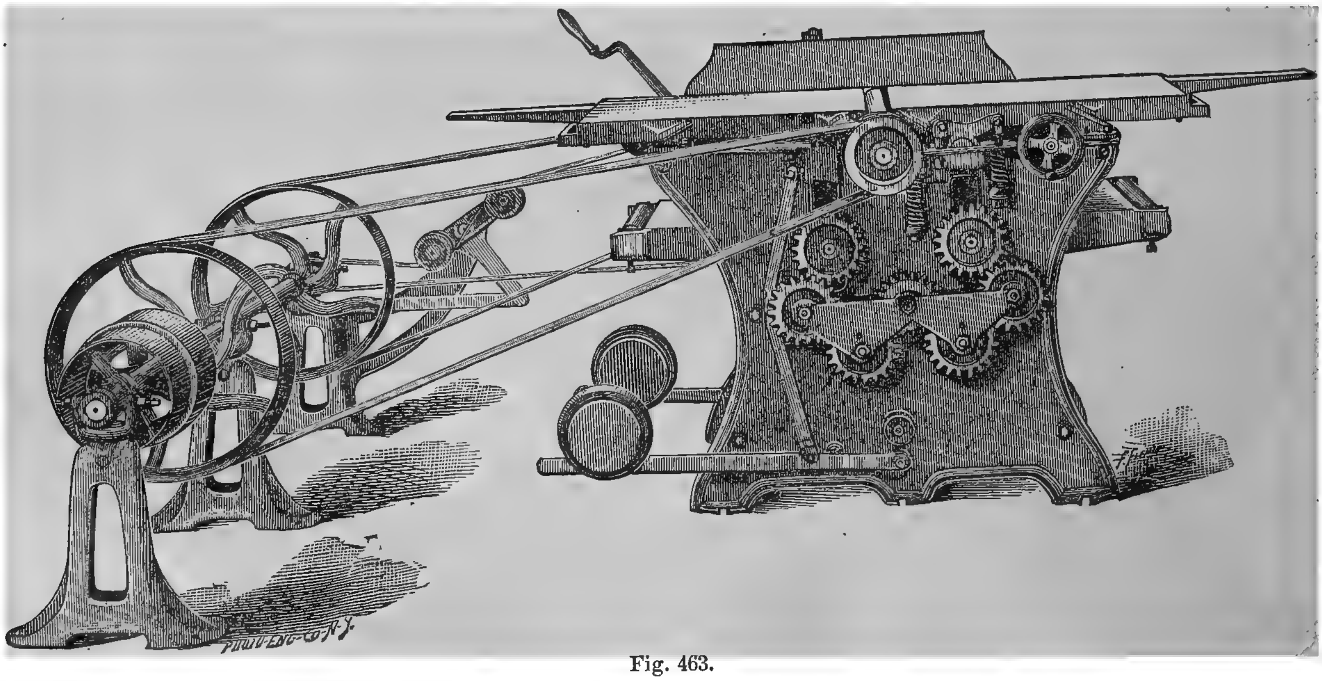


Fig. 463.

table for the hand-planer service is adjusted by hand-wheel. It makes a compact combination where both machines could not be kept full, or where both may not be required at once. As a principle, however, combination machines

are to be designed with great caution. The jointers previously discussed have been horizontal. For jointing small work, where finish is of moment rather than fit, a vertical machine such as Fig. 464 is approved. It is especially adapted for shingle-jointing and the like, and may be fed by two persons. The plane-knives make a drawing cut

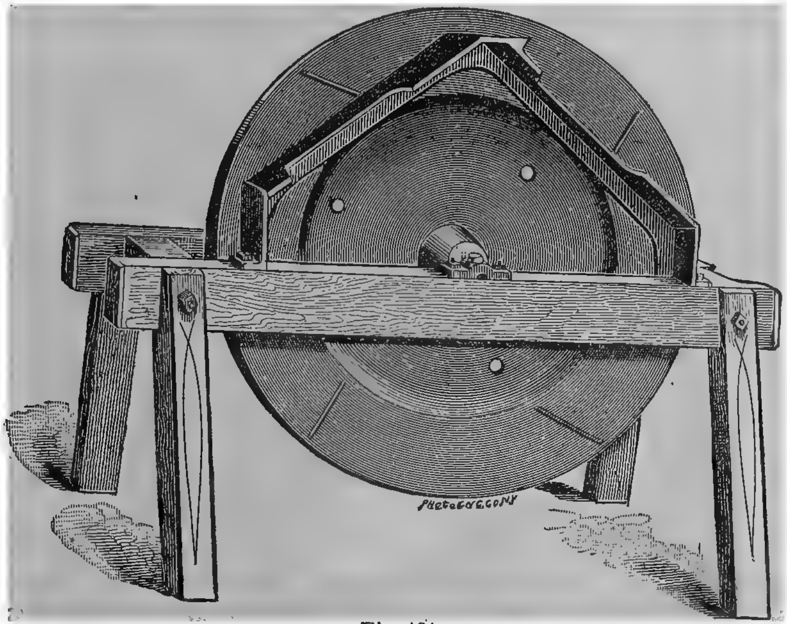


Fig. 464.

as they pass over and along the work. The stroke-jointer (Fig. 465) acts like a hand-plane, traversing back and forth over the work presented to it. It is, of course, adapted for edge work or more especially for jointing, and the stroke may be varied to economize time. The reciprocating knife gives a true and even surface. A knife on the

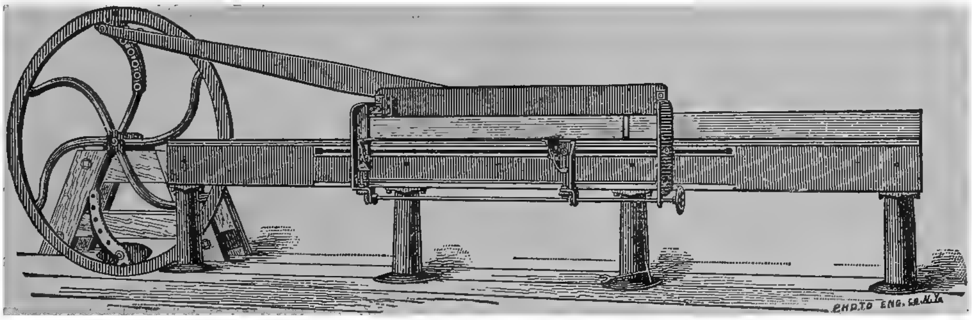


Fig. 465.

top of the plane-slide may be used for jack-planing. In jointing, the work rests upon the adjustable brackets shown. The tools of this class are finding an increasing application. Pattern-shops find them very useful for a great deal of their work. Better work is done on them when the pieces are heavy enough to help to resist the pressure of the cut.

§ 46.

SCRAPING- OR SMOOTHING-MACHINES.

To produce a smooth finished surface on hard-wood lumber which should show the grain it has been necessary to employ hand-labor. The surface has been scraped with a steel edge, slightly turned over into a shape not unlike the hook-scraper for metals. After this scraping process, the wood was ready to be filed and varnished. The scraping-machines of Figs. 466 and 467 *a* and *b* are designed to do by power that which has hitherto been done by hand. Fig. 466 is a small size in perspective, and Figs. 467 *a* and *b* show a larger size in end and side view. The scraper-knife is held stationary by a square holder in the lower table. The stock is fed over it by driven feed-rolls with expansion gear. The knife-holder is kept up by springs against bearing-screws, and the pressure of the lower rolls upward is also by springs. The upper platen and rolls are adjusted by screws together, worked by worms which are geared together in the larger size. The gearing is direct in the smaller. The lower hand-wheel, by compressing the lower spring, releases the stock or holder when necessary. The great obstacle in the way of these

machines hitherto has been the difficulty in securing the proper edge for the scraper. Although the machine has been on the market since 1857, the extended application of it has only begun since the introduction of the accessory machine of Fig. 468, for grinding and turning over the edge of the cutter. The cutter is securely clamped on a

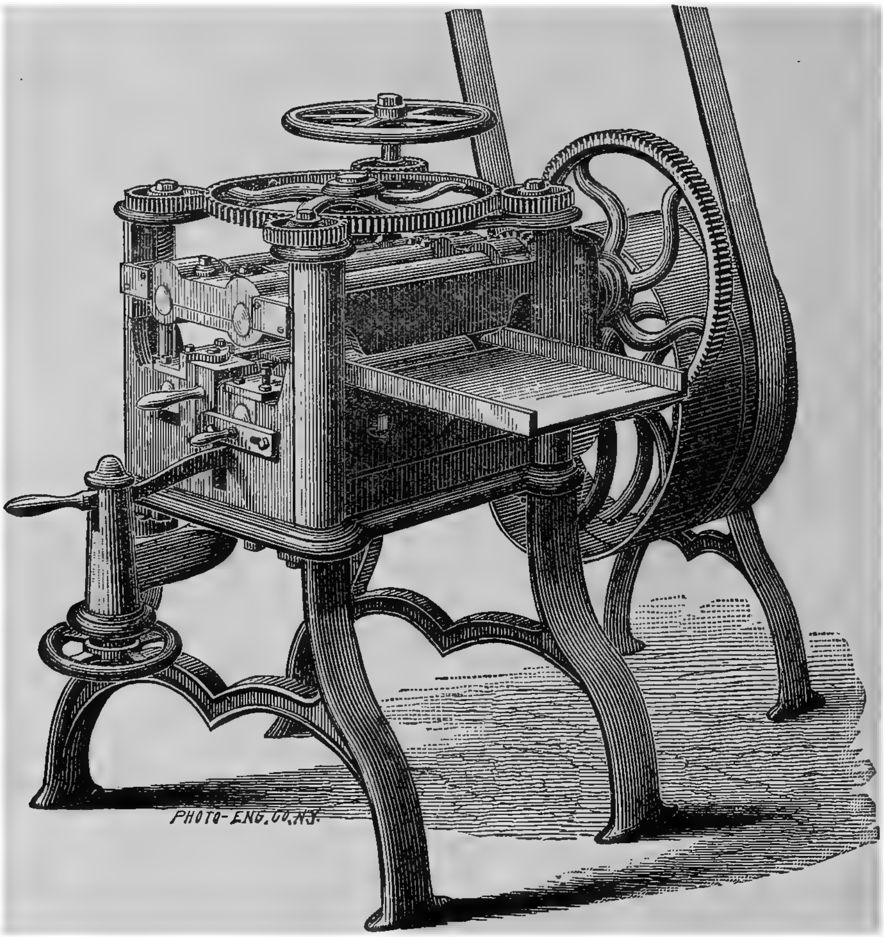


Fig. 466.

carriage, which slides back and forth upon ways under a pair of emery-wheels. The carriage is driven by a screw of steep pitch by open and crossed belts. There are two small emery-wheels, one acting on the face of the cutter,

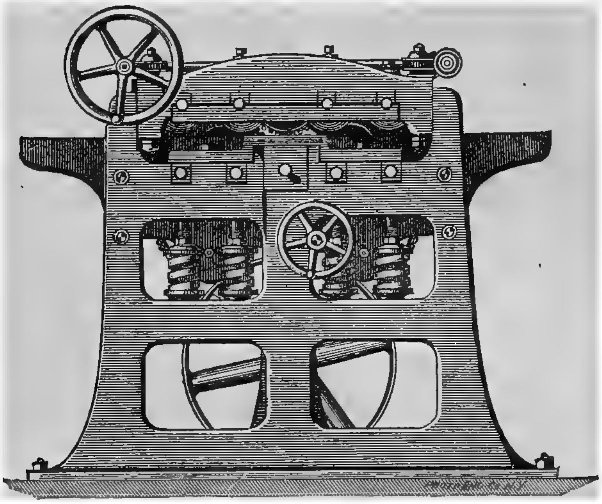


Fig. 467 *a*.

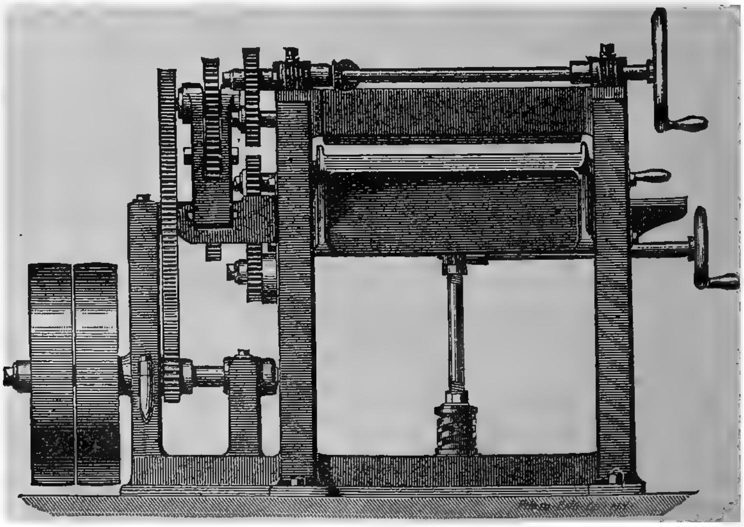


Fig. 467 *b*.

and the other in a different plane on the back. The rear wheel grinds a bevel of about 35°. After the edge is produced the emery-wheels are raised, and the burnishing-tool to the left of the emery-wheels is brought down to turn over the edge. The traverse is made by hand, and only once, while the the contact is lubricated by sperm- or lard-oil of heavy body. Great care should be taken to keep a perfect surface upon the burnisher. An exhaust-fan carries off the emery-dust from the bearing-surfaces.

The smoothing-machines are more especially adapted for the hard woods and for manufactured articles. They possess great interest as an instance of the direct replacement of hand-labor by that of a machine, with manifest gain in quantity and quality of work performed.

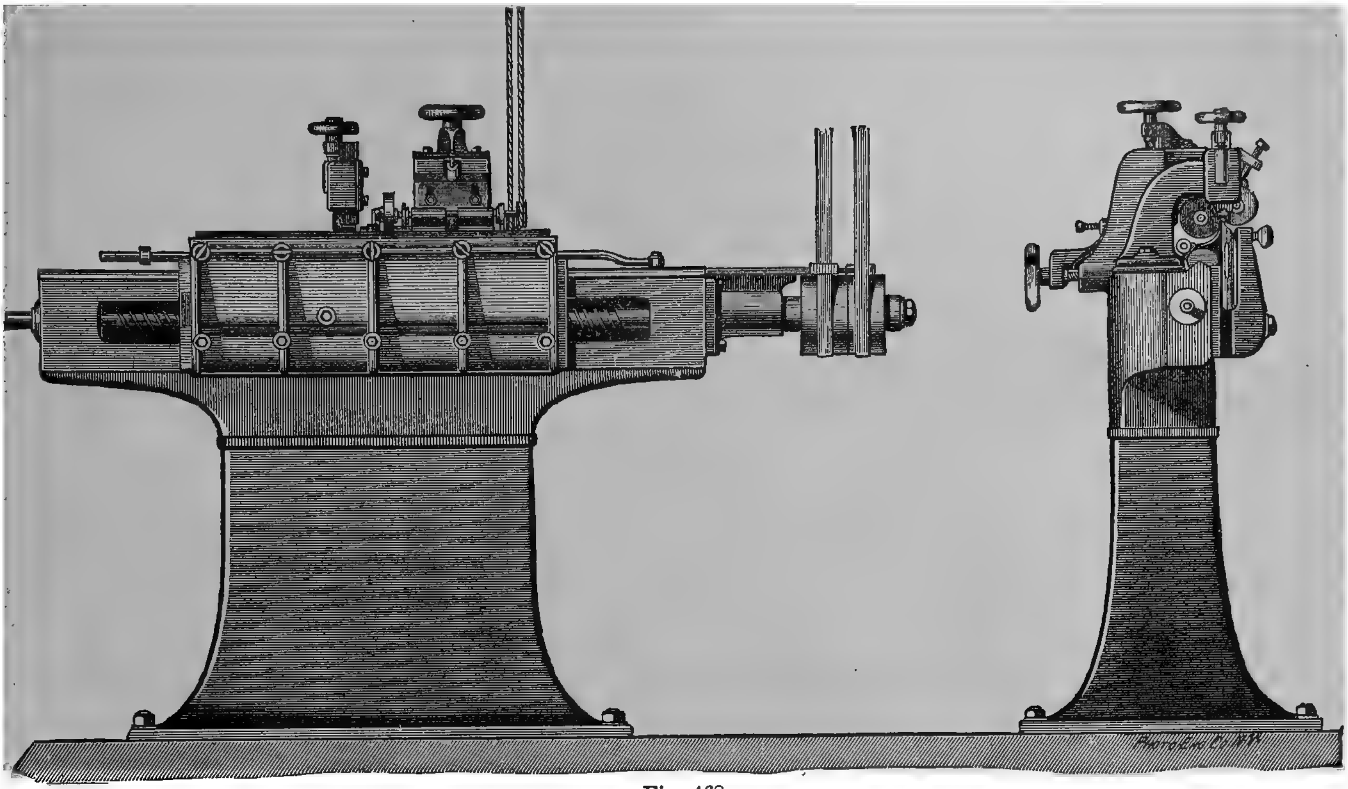


Fig. 468.

§ 47.

DIMENSION- OR CARRIAGE-PLANING MACHINES—DANIELS PLANERS.

The Woodworth planers, the roll-feed and lag-bed planers, belong to a class which might be called *parallel* planers. The upper and lower heads are not opposite each other, and each will act to produce a surface parallel to

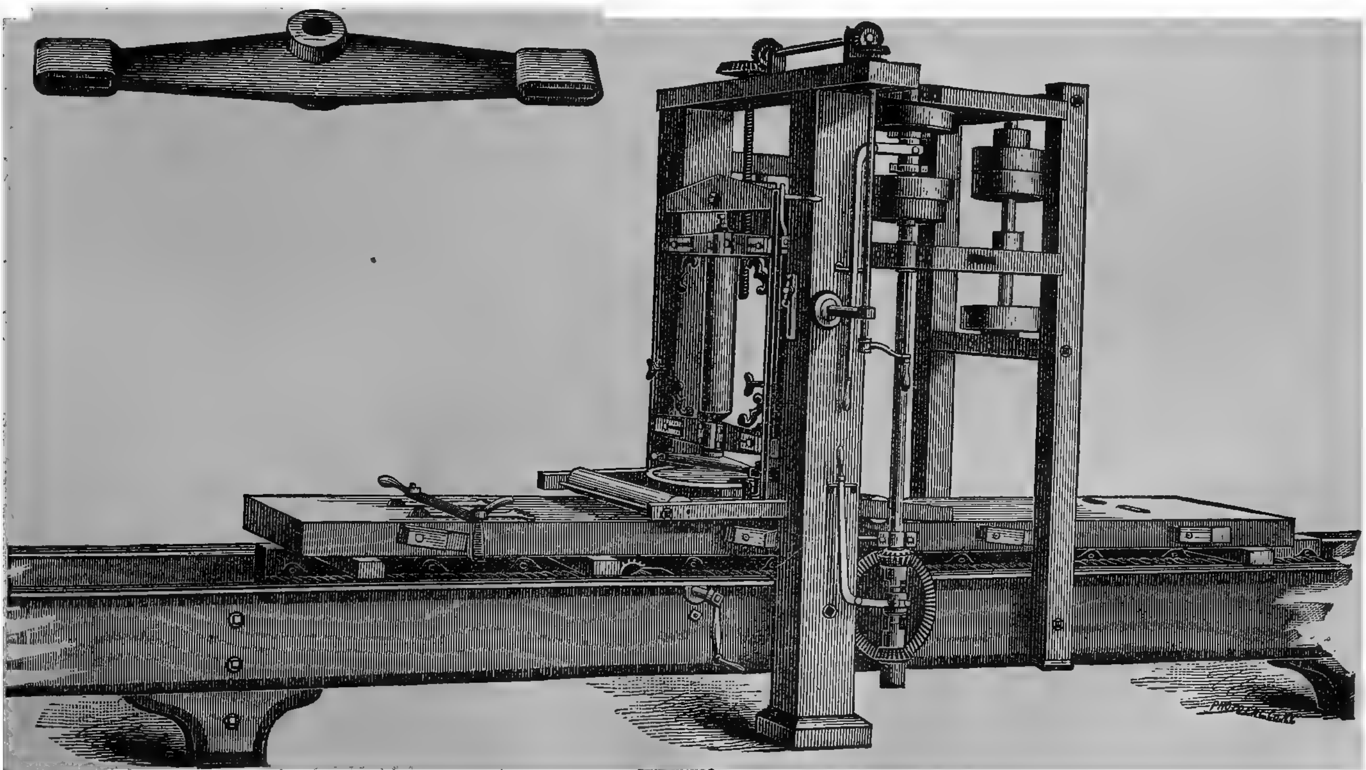


Fig. 469.

that which resists the pressure of the cut. This will be especially the case where the lumber is flexible, or where it is stiff enough to be in contact with the bed at a few points only. The resulting surface need not be a plane, nor need the finished stock be of the same thickness at all points of its length. Where the stock is to be true when planed, or of standard dimensions, it is necessary that it be dogged to a carriage which runs upon true ways. The passage of the stock under the cutters must generate a true plane surface on the top parallel to that of the ways. This one surface can be used as a base plane for working out the other three in rectangular work.

Fig. 469 shows the Daniels planer for this class of work, with wood frame. The two cutters are held in the ends of the arm shown in detail in the cut, and revolve transversely to the motion of the stock. This rotation is

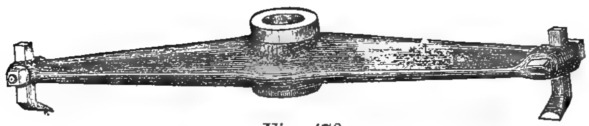


Fig. 470.

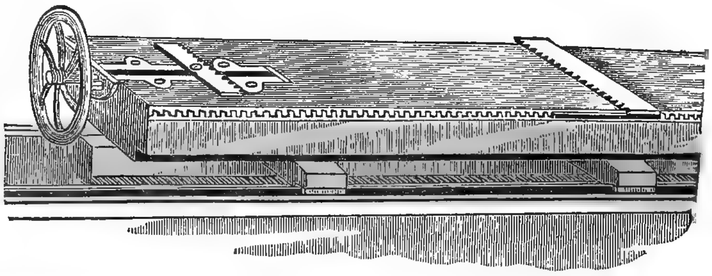


Fig. 471.

given to the long axis of the arm by a belt from a wheel behind, on a vertical shaft with fast and loose pulleys. Some designs use a drum at the back, arranged horizontally, and give the short belt a quarter twist. The cutters are borne in a sash-frame which is adjustable vertically by a screw for varying thicknesses of work. A cast-iron disk, known as the "dead-weight", hangs concentric with the cutters and serves to keep the stock to a plane when

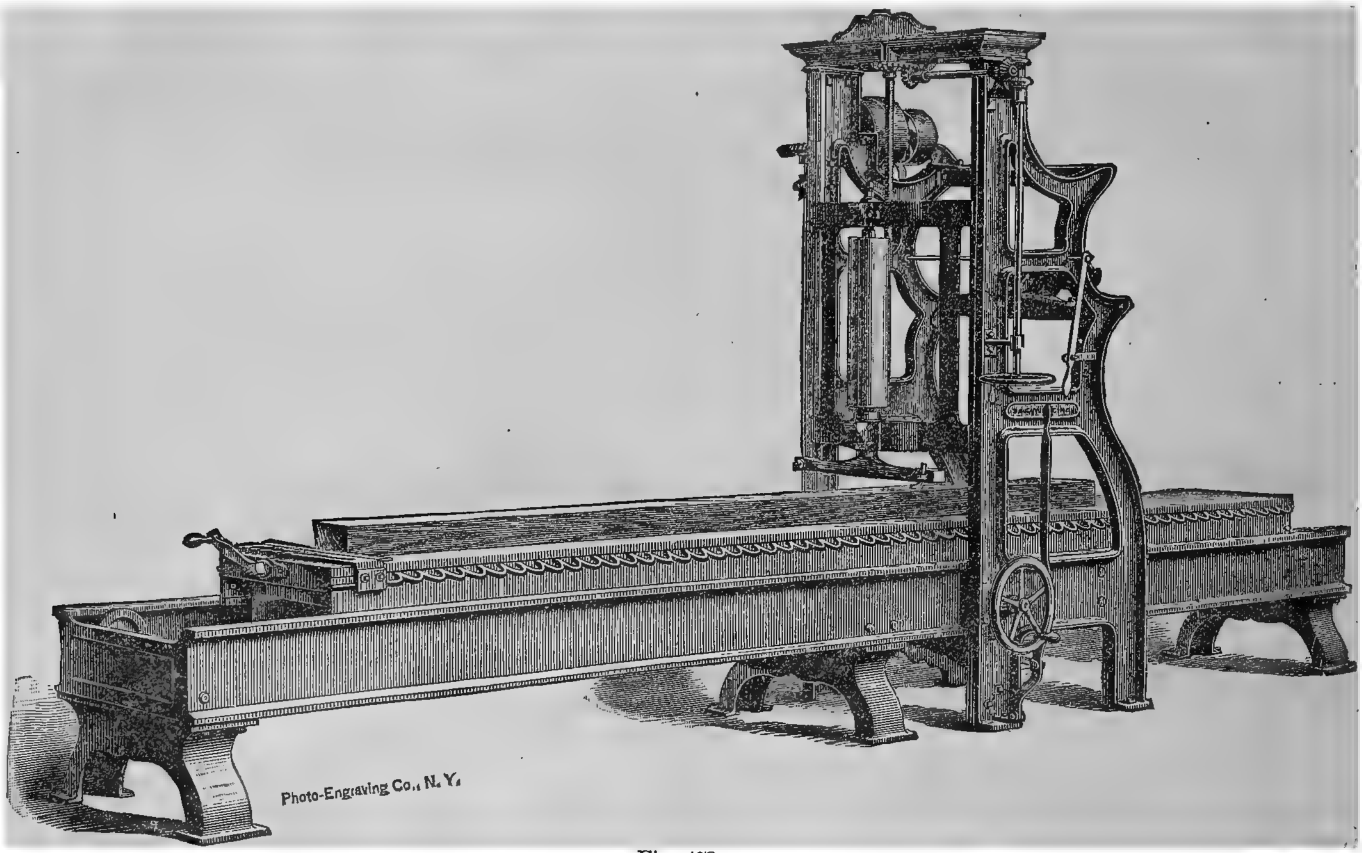


Fig. 472.

thin, and acts as a sort of chip-breaker also. A pressure-roll turns in a frame in front of the cutters. The carriage is fed forward by a rack in its under side. The rack is put below the driving-pinion, in order that there may be no tendency to lift the table. Motion is given to the driving-pinion by horizontal belts to a vertical shaft through a combination of two bevel-wheels and clutch. This makes it very easy by a motion of the hand-lever to arrest or reverse the feed instantaneously. A quick-return combination is secured by the upper clutch on the vertical shaft. For feeding forward the driving-shaft turns an idle shaft from which a further reduction is made to the gear-shaft, with choice of two speeds. For returning, the gear-shaft is belted directly to the driving-shaft, and with less reduction. The clutch engages the one belt or the other at will, independent of the reversing-gear below. A loose crank permits easy adjustment by hand.

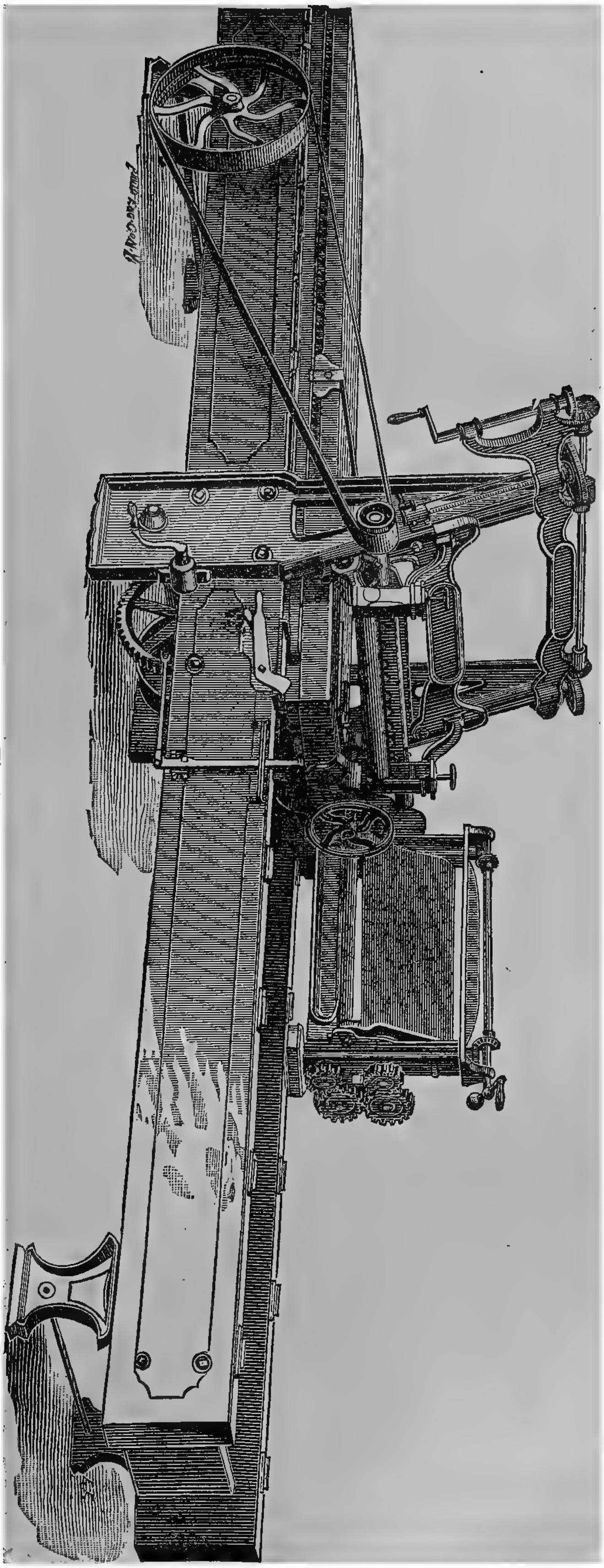


Fig. 473.

Fig. 470 shows a different form of cutter-arm with the usual cutters. The bolts have a hook-head, and the cutters come nearer to the ends of the arm. They also come central to the arm instead of in front of it, diminishing the leverage of torsion. For securing the work to the table, the cheaper device is by means of the toothed flats which are held in place by a clamped cross-bar. The toothed ends are driven into the end of the stuff.

Fig. 471 shows a screw-dog, where the serrated edge moves forward by the hand-wheel and the abutment only is adjusted for different lengths. It will be seen at once that the bed of the Daniels planer must be more than twice the length of the table, and the latter must be longer than the longest piece the machine is ever expected to accommodate. The great length of bed makes the machine a very bulky one, and has made many builders continue

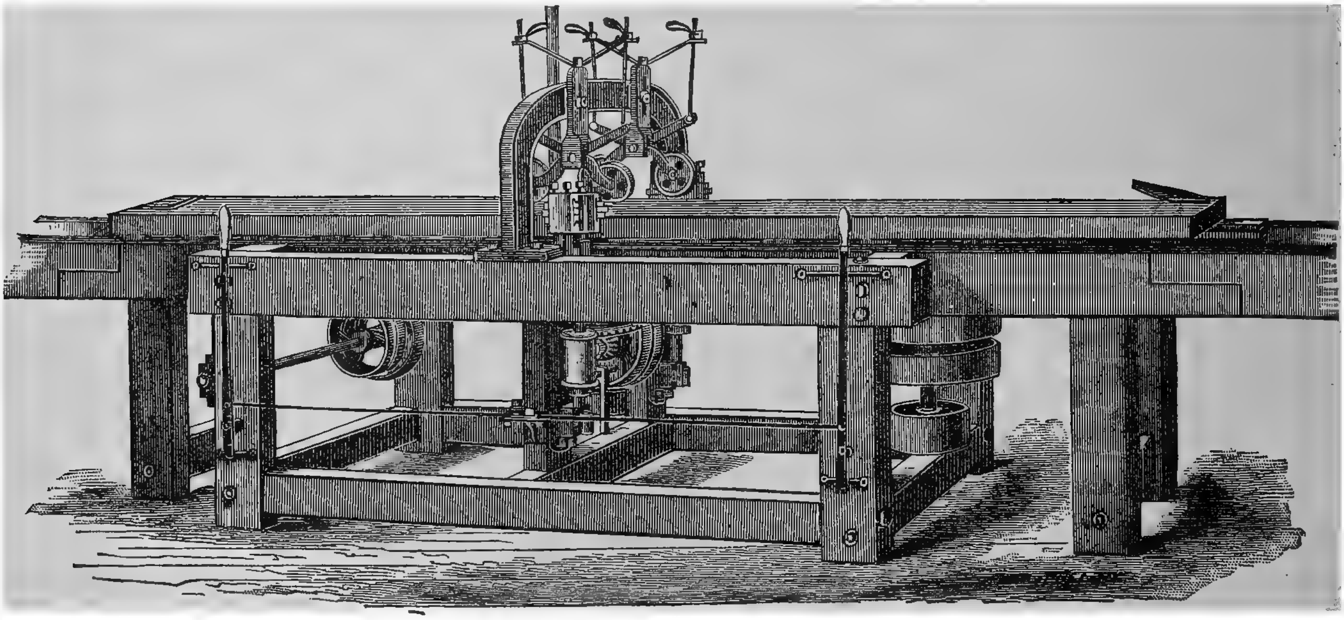


Fig. 474.

to make the framing all of wood. One or two are using iron uprights on the frame bolted to a wooden bed. There are objections to this, inasmuch as the wooden parts yield to atmospheric influences which do not affect the iron, and the excellence of their work is thereby vitiated. The high-grade machine is the one with metal framing, although its relative expense stands in the way of its extensive use.

Fig. 472 illustrates one type of the iron-frame planer, with the feed mechanism on the farther side. There are the same capabilities as in the other. While the transverse action of the cutters does not tend to distress or

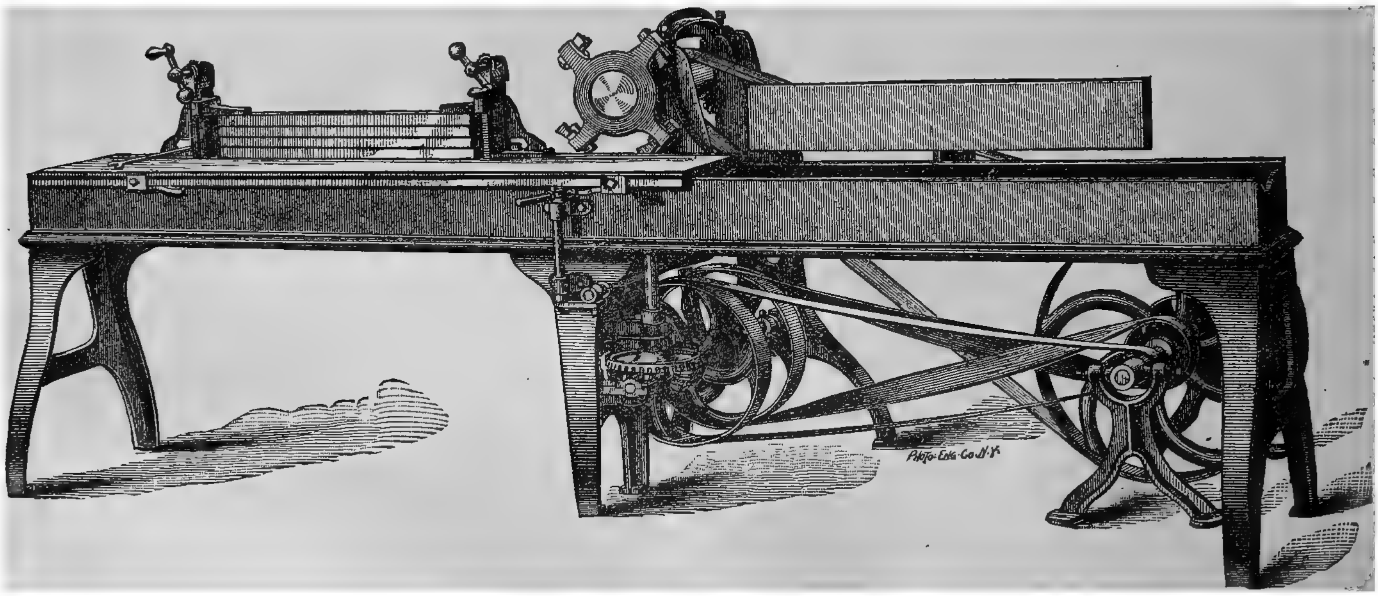


Fig. 475.

displace the lumber which is being trued, their action is slow. To remedy this difficulty, the rotary cylinder of the Woodworth planer has been fitted parallel to the traversing bed. It is made adjustable by screws for varying thicknesses and carries its own spring-pressure bars or rolls.

Fig. 473 illustrates a machine of this design. The adjusting-screws are outside of the uprights, and are geared to the convenient hand-crank. The machine will plane true and out of wind as well as the old, and has great advantages in the long life of the cutting-edges relatively to those of the transverse planer, and in the rapid feed. The same figure illustrates an attachment of feeding-rolls for the use of the machine on the pure Woodworth principle. The carriage being locked stationary, the stock is fed over it as in the typical machine. An iron plate which hinges up against the upper roll turns down upon the carriage to protect the wood from the wear of the friction of the stock. The roll-gear is hung upon a long hinge at the back, so that the operator does not have to lift its weight, and the rolls are geared to the feed-train by a special device. The passage, therefore, from a planer of one system to a planer of the other is made very simple and easy.

The principle of carriage-planing has not been extensively applied for double surfacing. There are but two or three such machines in service. Fig. 474 illustrates one of these for double surfacing or matching. The rotary cutters are opposite each other, and adjustable spring-pressure rolls keep the stock down while the dogs hold it from endwise motion. The feed-motion is very simple. A machine of iron frame, with a third cutter-cylinder lying horizontally across the bed, can surface three sides at once with corresponding gain in time. The principle of Fig. 475, which has a Daniels head with four knives on its side, may be doubled for double surfacing. The machine shown is designed for jointing, but can be applied otherwise. The thrust of the work is borne by a thrust bearing in the grooved surface of the babbitt. The reversal of the feed is effected by stops at the side of the carriage. It is no doubt the comparatively slow feed of the Daniels planer which has caused its slower development than the parallel classes of planers. While the earlier speeds of less than 20 feet to the minute are much exceeded to-day, the limited capacity of the machine has restricted its use to the shops which handle larger and heavier sizes of lumber for car, bridge, or other engineering purposes.

§ 48.

MOLDING-MACHINES—STICKING-MACHINES.

The paring-machines of the previous discussion have been intended to produce plane surfaces. The next class includes those which act to produce profiles or ornamental cross-sections at right-angles to the length of straight stock. These diversified cross-sections will be produced by rotating cutters or knives whose action is identical with that of the surfacing- or matching-heads of the planing-machines. In fact, many kinds of molding with flat top and bottom, and profiled only on the edges, may be made on any matcher by the exchange of the matching-cutters for those of suitable profile.

Fig. 476 illustrates a standard type of internal molding-machine for working molding-stuff upon four sides. It differs in width from the planers of the same builders, but has the same mechanical excellences. The stock must be guided laterally to secure a straight and uniform profile, and these are provided to be set at any part of the table. The lower head surfaces the base of the shape, and is a plain straight knife. The upper and side heads carry knives ground to the desired profiles.

Fig. 477 shows a number of types of head which are in use for a variety of purposes, with the knives in place. The side heads have lateral adjustment by screws for widths, and the boxes of the upper head have an endwise adjustment to bring the knife-profile exactly where it is wanted relatively to the other two. This may also be done if required for the lower head. The adjustment is by screws.

Fig. 428, of the planers of the same make, shows how the side heads are clamped to a round bar to prevent back-lash or tremble. The cylinders of molders usually are fitted with balance-wheels to equalize the motion when the knives are not symmetrical with the cylinder. The cylinders have two or four sides, for better equilibrium. A special form of pressure-bar is required to hold down the moldings after their tops have been shaped. Adjustable hinged cross-bars are fitted with a foot, which ends usually in a wooden sole, complementary in shape to that of the molding. These feet can be adjusted laterally and vertically upon the cross-bars, and thus steady the work beyond the cutters. Where the moldings are worked from rectangular stock the first rolls and bar may be straight and of the planer type. A notable economy in chips and lumber may be effected by previously sawing the stock into an approximation to the required cross-section, the saw-kerf perhaps entering the two sides of the squared stock at different angles.

The heavy black line of Fig. 478 represents the one kerf by which two molding-blanks are separated and the work of the molding-cutters is lightened and lumber is saved. For blanks of this sort a sectional pressure-bar is a feature of this manufacture.

Fig. 479 shows a sectional view of the cutter-head, with a number of separate feet resting upon the various parts of the profile. Such pressure comes near the cut, and each, being weighted, acts to help to cause smooth work. By the use of a number of heads with separate or sectional cutters on each (Fig. 480) it is possible to work out quite varied patterns. Each knife finishes a part of the profile in succession. By having the side heads adjustable laterally below, the crowns of moldings may be cut with a knife of durable shape. Projecting fine points in a profile are apt to burn off. Such a picture-molding as Fig. 480 in older practice would have been

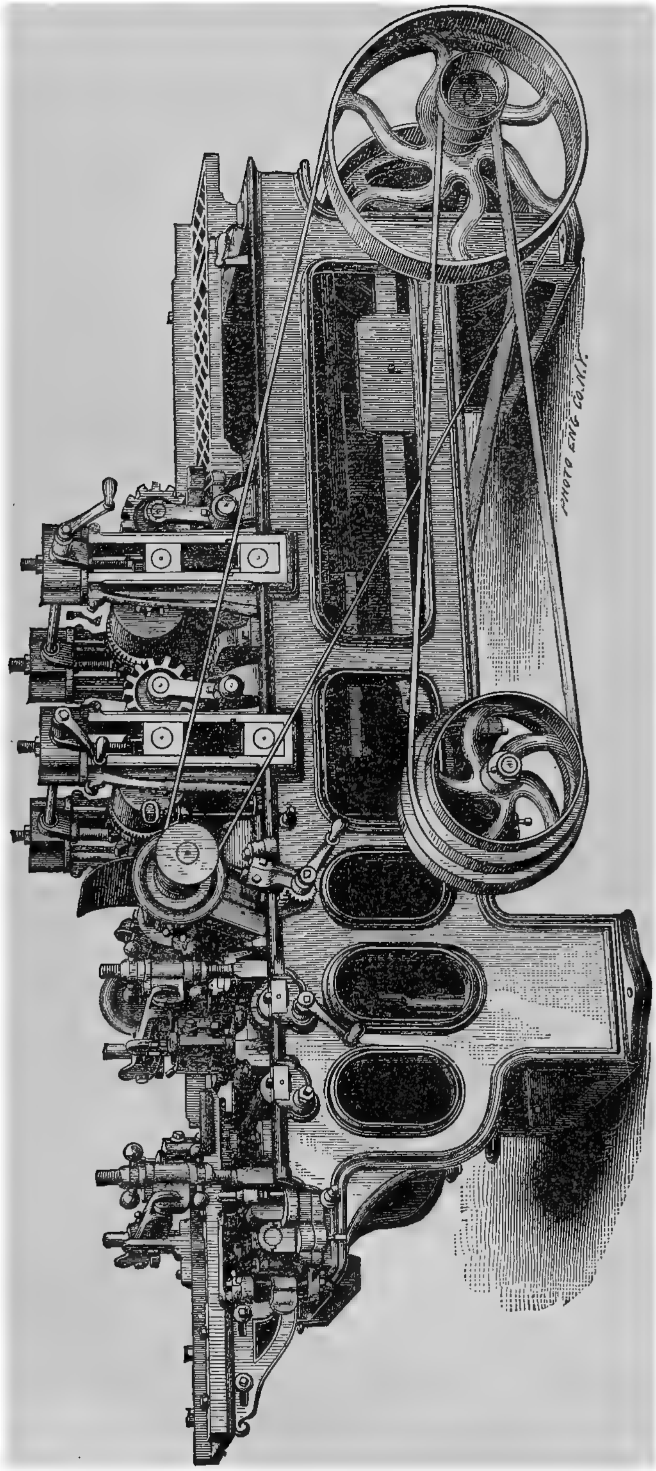


Fig. 476.

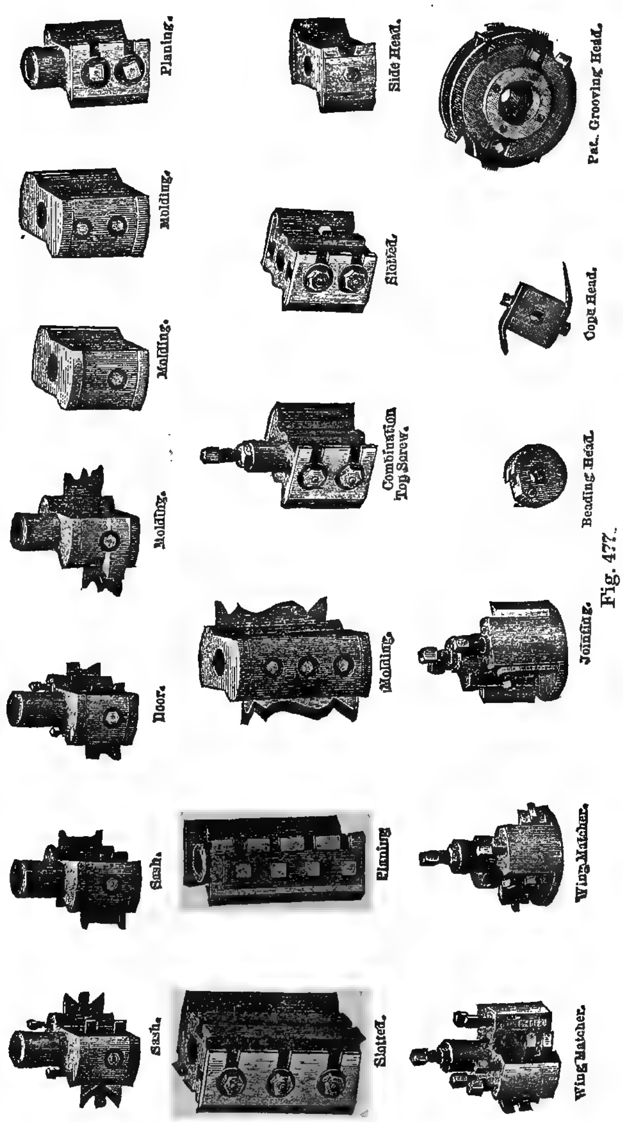


Fig. 477.

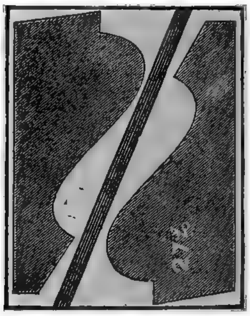


Fig. 478.

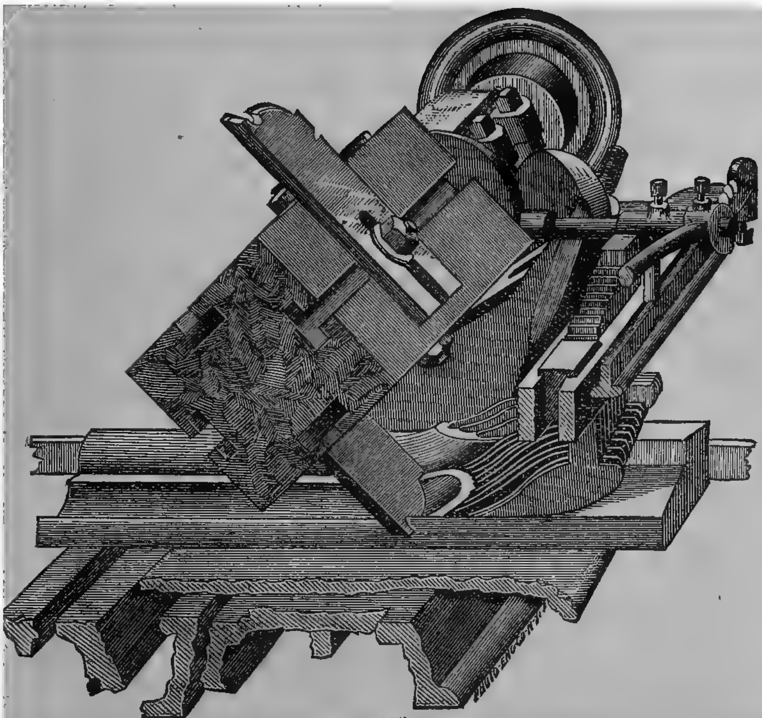


Fig. 479.


Fig. 480.

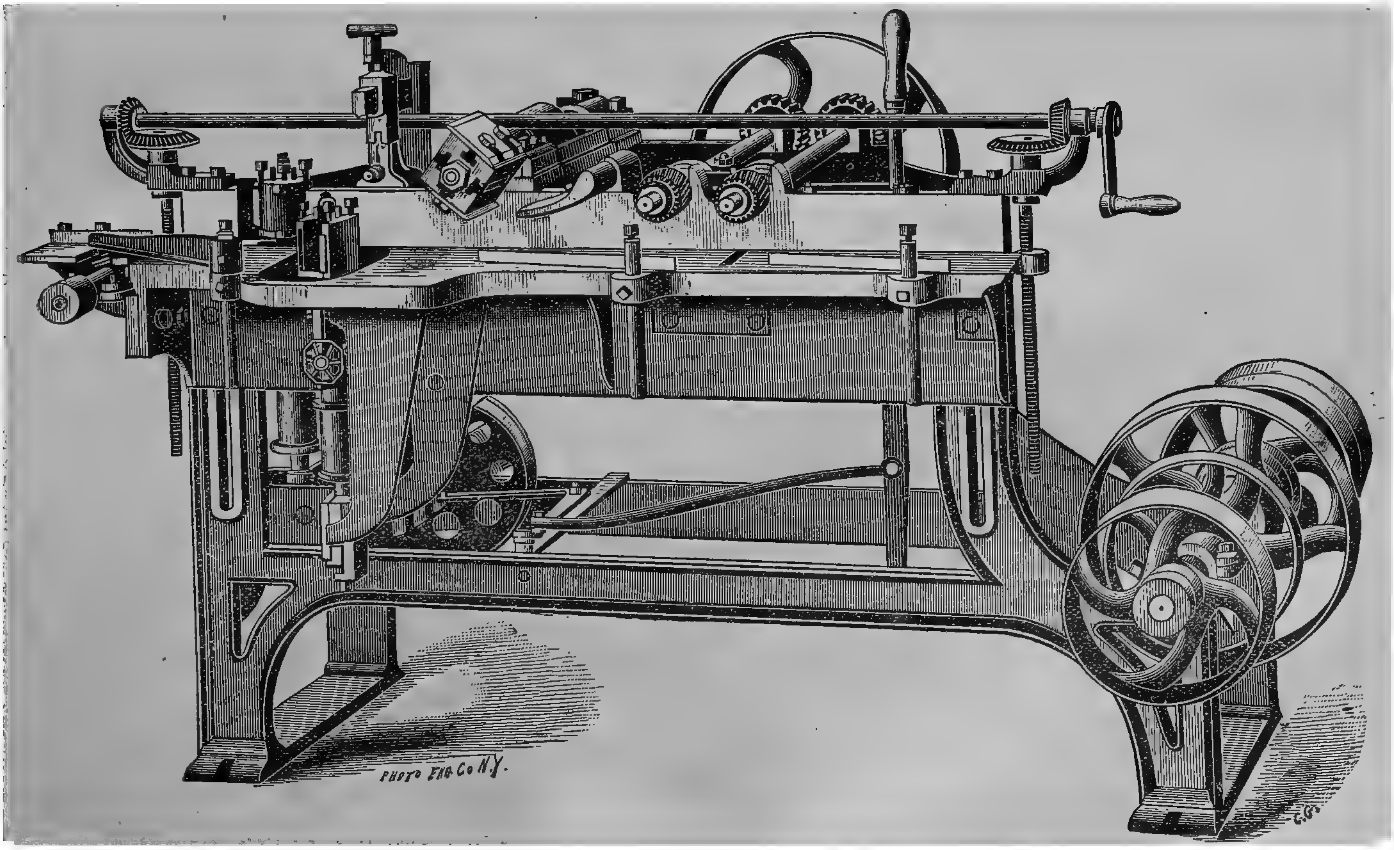


Fig. 481.

made in two pieces and glued together with a tongue. There are many classes of shops for which this type of inside molder has advantages. They will surface and match, if required, usually up to 10 or 12 inches wide, and may be used for ceiling- or flooring-stuff as well as for moldings. But on account of the greater accessibility of the heads for adjustment and for sharpening, what is known as the outside molding-machine or "sticker" is preferred, where the surfacing duty will be for narrow work only.

Fig. 481 shows one type of such a machine especially designed for sash and blind or similar work. As in all machines of this external class, the upper cylinder is stationary and the other three are attached to the table, which rises and falls by geared screws. The side heads adjust vertically and laterally, and there are take-up devices at

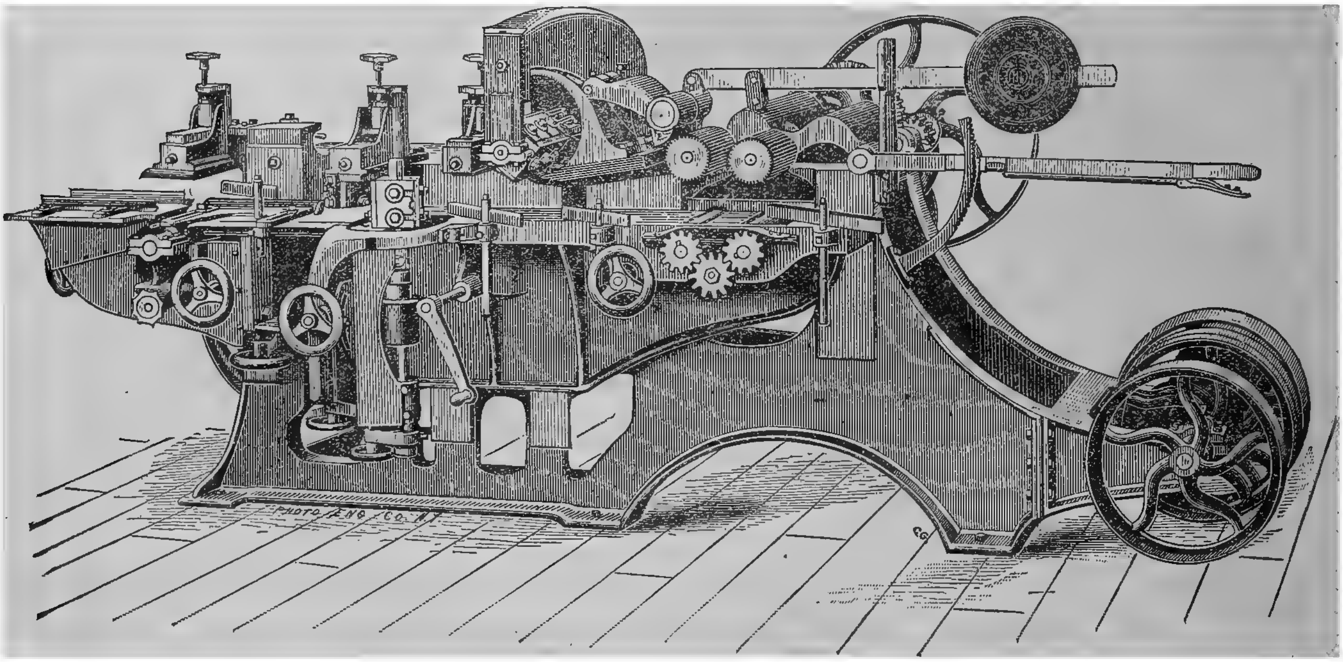


Fig. 482.

the foot for angular motion and to prevent chatter from wear. There are two pair of rolls driven by power engaged by friction-clutch below the table. These give a strong feed, and the upper rolls are fluted with spiral grooves, which tend always to feed the stock against the side of the frame which acts as a guide. There are springs adjustable in lugs in the table to keep the stock firmly in line and in contact with the frame. A solid pressure-bar and chip-breaker lies in front of the upper head, and an adjustable one with a foot holds the profiled stuff for the

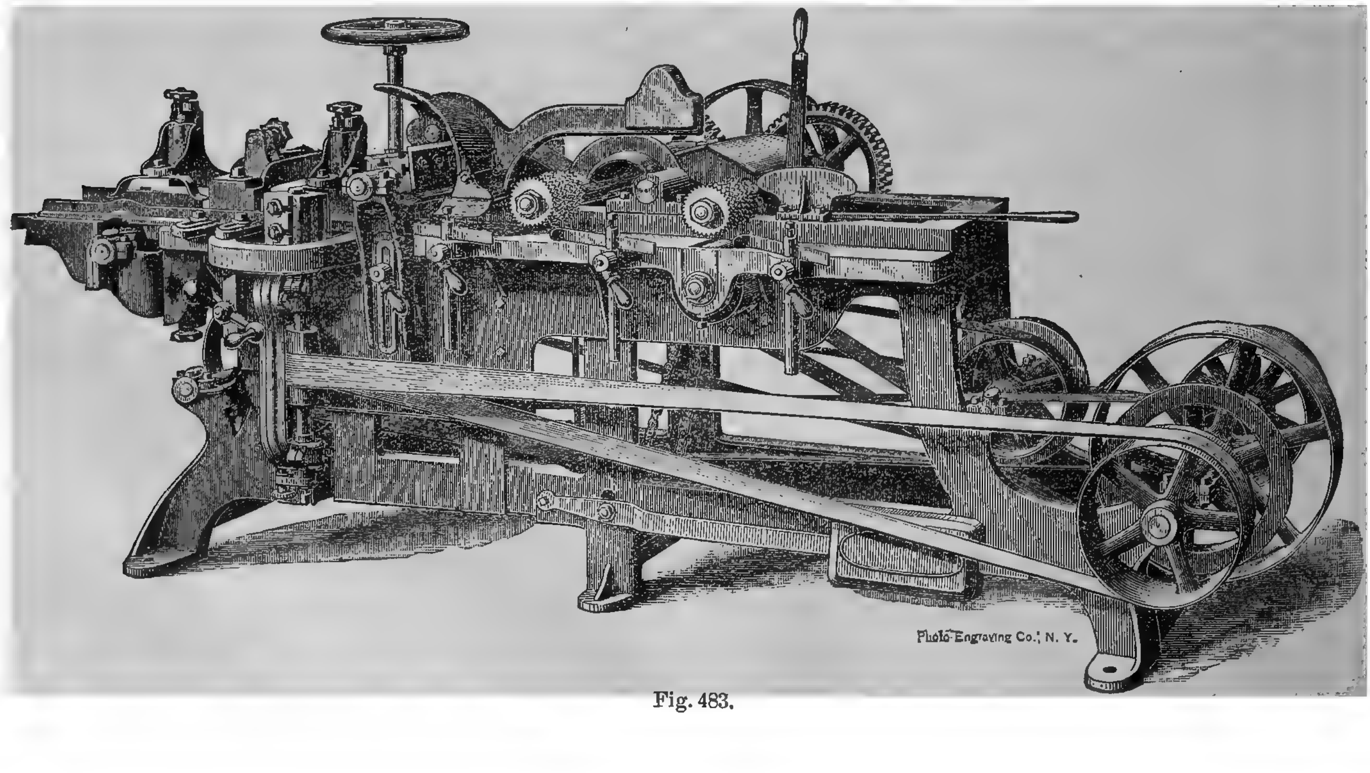


Fig. 483.

side heads. These latter are not put opposite each other, in order that there may be no danger if it is desirable that the cuts of the two sets of knives should overlap. The machine shown has the upper head overhanging. This is wise and possible for narrow machines. Where the work is to be heavier and wider the outer end of the spindle should be supported.

Fig. 482 shows a machine for molding 10 by 4 inches, with the spindle supported by an arm overhead. This system leaves the table free at the side. The feed-rolls are heavily weighted and fluted, all the rolls being driven. There are three pressure-bars, arranged with holders for sections of wood to fit the profile. A chip-breaker is in place in front of the upper head. The side heads have all the usual adjustments, lateral, vertical, and angular. At the further end of the table, beyond the under cutter, a section of the table is made adjustable, and is arranged so that a diagonal smoothing-knife may be mounted at that point. Beside the heavy gibbed slides for steadying the table, the ends may be bolted to the frame by a screw-bolt in a slot. The lifting-screw is geared to a horizontal shaft coming out in front. The counter-shaft is bolted to an extension of the bed-plate.

Fig. 483 shows the type where the outer bearing of the head is attached to the table, which must rise and fall behind it. The upper rolls are of a spur-tooth or serrated profile, arranged to lift perpendicularly. The lower

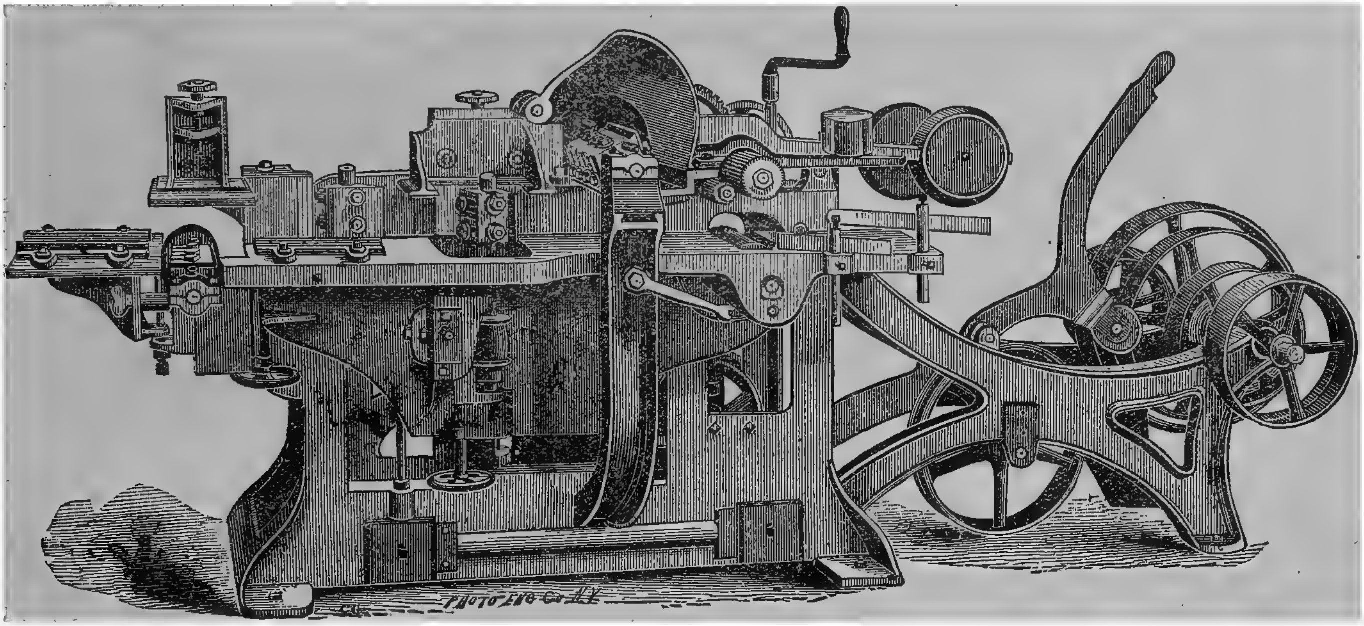


Fig. 484.

rolls are smooth, and are also driven. The upper rolls are so hung upon a crane-like frame that they may be lifted from the stuff by a lever at the rear if desired to arrest the feed. The use of gearing-chain is to be noticed. The shaving-bonnet and pressure-shoe are pivoted in front of the cutter-cylinder so as to follow the knives closely, and can be swung entirely clear for access to the cutters. The lower cylinder has a separate vertical adjustment independent of the bed, so that its cut may be varied without shifting the knives. The upper cylinder-boxes are held in a gateway, which is gibbed to the frame for easy lateral adjustment. In Fig. 484 the outer bearing is supported from below the table, and independent of it. The bolt in the slot gives additional security. Its other features are sufficiently obvious. The molding-machines of this class are specially adapted for shops which make a specialty of builders' moldings, and require to turn them out in large quantities. This work they perform very rapidly and very well.

§49.

UNIVERSAL WOOD-WORKERS—VARIETY WOOD-WORKERS.

The growth of small wood-shops at distances from the large centers has made a demand for a machine which shall have many other functions beside that of turning out linear moldings. To these the name of universal or variety wood-workers is given, on account of their large capacity for different kinds of service. One side is made entirely independent of the other, so that there are really two machines. One side is known as the molding-side, and the other half is called the wood-worker side. Fig. 485 shows a perspective view of such a machine, and Fig. 486 illustrates the molding-side. There are *five* heads in use at once, of which two act upon the upper side. These may divide the cut if it is heavy, or one can be used to take out dirt and make a rough cut, while the second finishes the upper surface. The lower head acts first at the front to plane the lower side of the material smooth

and out of wind before it reaches the molding-heads. The side heads rise and fall with the table, and have separate adjustments horizontally, vertically, and at an angle. A pressure-bar with wood foot lies between the two upper heads, and the shaving-bonnet may swing out of the way of the knives. Four of the cutter-heads have helical cutters, giving a dragging or shearing cut. The fifth is parallel and slotted. The feed-rolls are serrated,

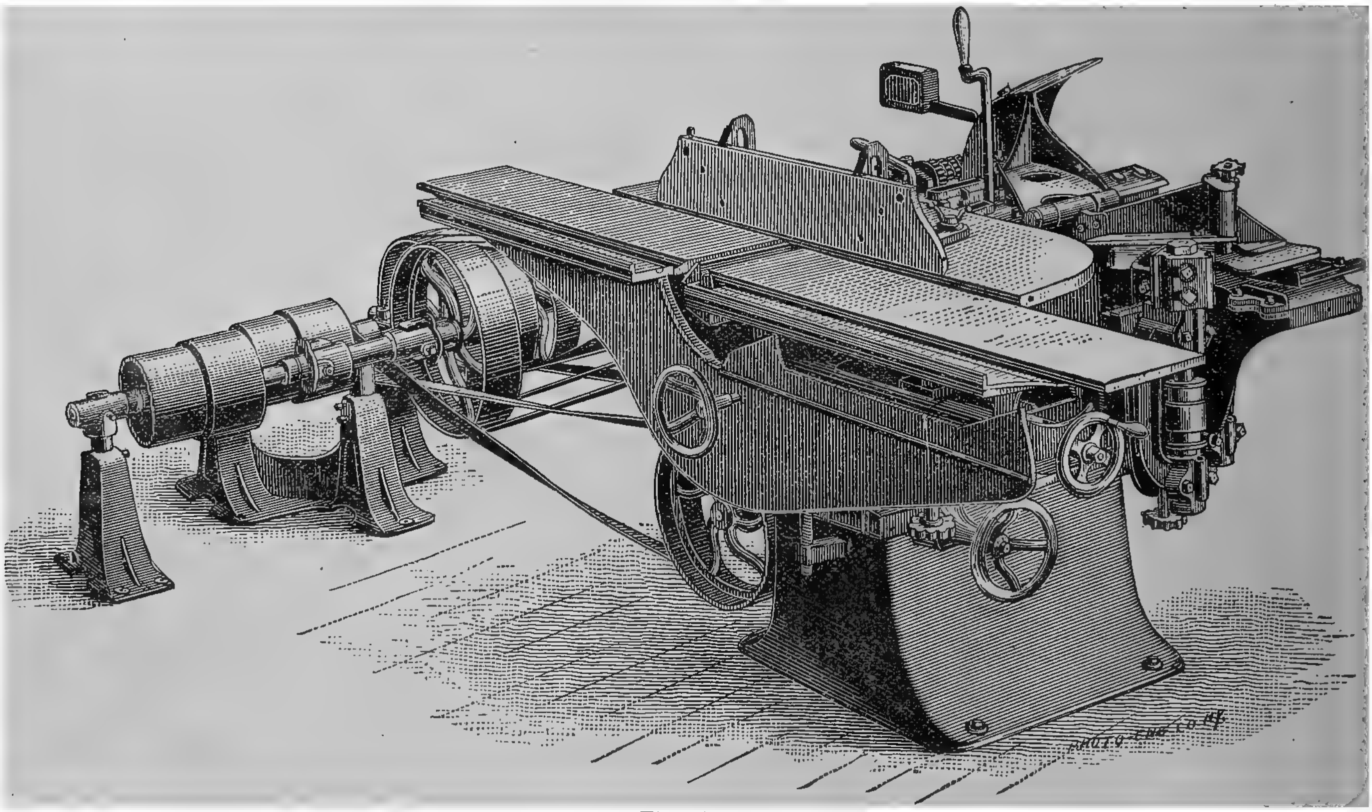


Fig. 485.

and are kept to their work by weighted levers. The form of platen for the outgoing end is more plain in the previous cut. The construction of the wood-worker side is essentially like that of a buzz-planer. The whole table

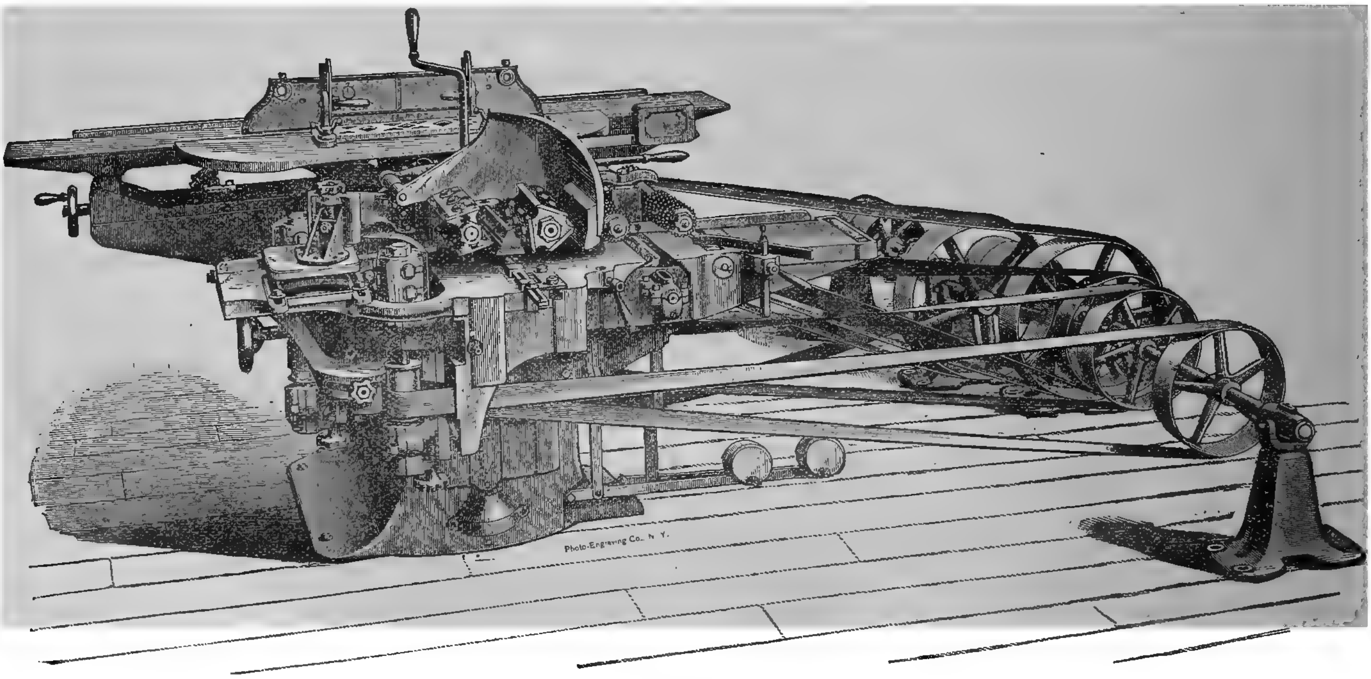


Fig. 486.

lifts and lowers by screw and hand-wheel; each top has a horizontal motion to and from the cutter-head, and both tables have a vertical adjustment on inclined planes by screw and hand-wheels. The two tables may be brought

Fig. 487.

together over the cutter-spindle to guard against accident, and their accidental motion is prevented by thumb-screws and a rack with special pawl. The fence gives wide capacity for chamfering and bevels. The plate (Fig. 487) shows twenty-four different positions or applications of the machine. The numbers indicate respectively:

1, 2. Tables slide laterally, raise and lower, recede and advance toward the cutters.
3. Planing out of wind, jointing, squaring and smoothing.
4. Beveling, cornering, and chamfering.
5. Chamfering between the ends.
6. Cornering with chamfering form.
7. Tapering.
8. Mitering.
9. Rabbeting head and iron.
10. Rabbeting.
11. Tenoning.
12. Rabbeting and jointing blinds at one operation.
13. Panel fence, iron and head.
14. Panel-raising, both sides at one operation.
15. Tonguing, grooving, hand-matching.
16. Rolling-joints.
17. Making two plows at one operation.
18. Serpentine and waved molding.
19. Planing and fluting banisters.
20. Ripping and splitting.
21. Cross-cut sawing.
22. Gaining at right angle.
23. Gaining at any angle.
24. Circular, oval, and elliptical moldings.

These operations are permissible without adding special machinery to a fundamental machine. It is only necessary to mount the proper cutter-head and to adjust the fence and tables. Their universality has made them very popular, especially where the amount to be done of certain classes of work is too small to pay the interest on a special machine. This is likely to be the case in small shops and in small settlements. There is considerable variety in the forms of the universal wood-workers, although certain features must be retained in them all. An older design has a boring and routing table opposite the wood-worker side, and the latter can be rapidly changed from a wood-worker to a molding-machine for two sides by dropping the table. By fitting a proper head on the vertical spindle the machine may be used as a single-spindle shaper or friezer. It is made reversible by two friction-cones, engaged at will with a third between them by a foot-treadle. In one class of designs the cutter-head has an adjustable and removable outer bearing, as in the sticker of the same builders. A design of solid-frame variety of wood-worker, without the molding facilities which make it a universal machine, is shown by Fig. 488. The cutters

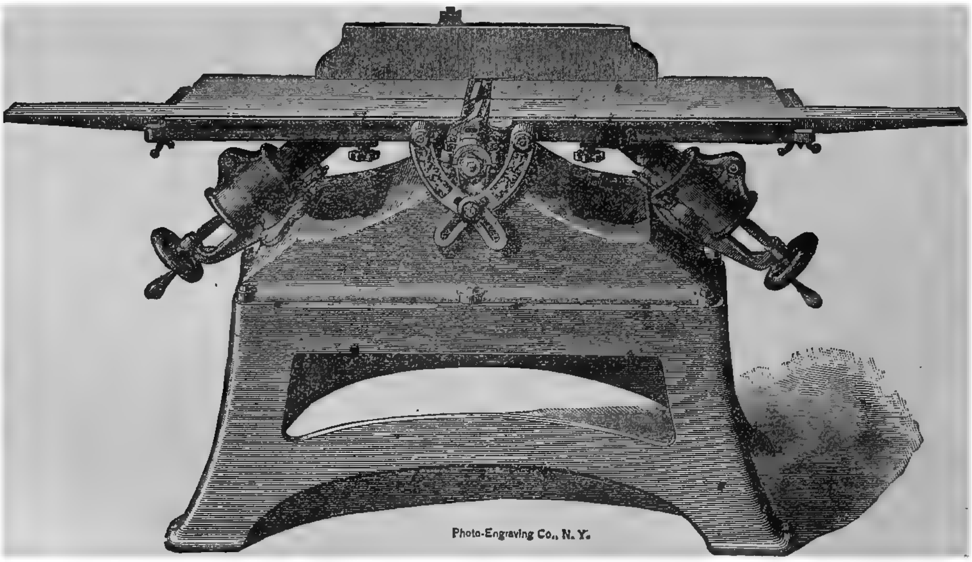


Fig. 488.

are helically arranged, and the two tables have separate adjustment by the plunger-bearings and screws. The head has outside bearings on the frame. Other designs have a columnar bed, with an arrangement by which the fence requires no separate adjustment. It retains its proper position relatively to the cutters by virtue of its

attachment to the forward table. It has lateral and angular adjustment, and may receive springs for holding down the stuff. When such machines are used for sawing, the usual tables are separated and a special one fits between them. Sawing is, however, not a legitimate use to which to put such machines. The broad scope of these universal and variety wood-workers adapts them to meet diversified needs; but where certain alternations would have to be frequently made, or where a certain class of work would keep a machine full and its operator busy, it is policy to have a special machine. Where, for instance, a quantity of tonguing and grooving is to be done to match small boards or tapering, such a machine as shown in Fig. 489 would be used. Taper or small work cannot

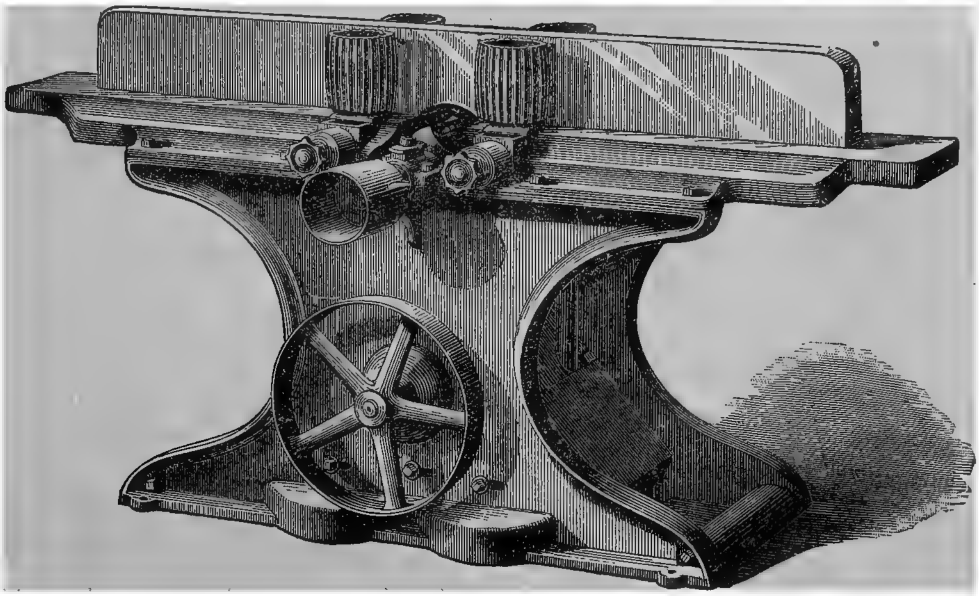


Fig. 489.

conveniently be matched in a large machine, and to do it on the wood-worker demands an entire change of head from that suitable for its usual functions. The same is true for panel-raising and edge-molding, to be discussed in the sequel. The machine of Fig. 489 has the central fence stationary, and the rolls and cutter-heads are adjustable horizontally for differing thicknesses of lumber. The rolls are heavily driven by gearing below, which is protected by the guards shown. Changes of feed can only be made by changing the large pulley below the cutter-axis. The fence carries friction-rollers, and the stock is fed in one direction to be grooved. It is returned in the reverse way on the other side of the fence, to be tongued by the other head. The feed may be by hand, if preferred. Such a machine may be found very valuable, either supplementary to the wood-worker or as a machine by itself.

§ 50.

EDGE-MOLDING OR SHAPING-MACHINES—FRIEZING- OR CARVING-MACHINES—PANEL-RAISING AND DOVETAILING-MACHINES.

Under this head is included a large class of machines which carry vertical spindles, fitted with rotary cutters at or near the top, which latter act upon their ends or sides. The machines are designed to produce profiles upon the edges of surfaces which could not be reached in the typical molding-machine. The edges to be profiled are often internal, and very often are curved, both of which conditions are prohibitory to the other type. Usually the feed is by hand, guided by formers or templets to which is secured the material to be operated upon. The templet bears against a collar on the spindle. These tools are very nearly on the line between the paring-tools and those which act across the grain also. Most frequently they act by paring.

Inasmuch as in a curved molding the grain runs in opposite directions on its opposite sides it becomes necessary to have either two spindles revolving in opposite directions or else to have the one spindle reversible. The latter is perhaps the newer practice. Fig. 490 illustrates the type which has long been standard. The two spindles are driven by quarter-twist belts from the counter-shaft at the rear. The pulleys on the spindles are very wide and crowning, and a flange at the bottom acts also as a balance-wheel. Instead of one upright, many builders make a framed bed, the spindles being supported on cross-girts between the two sides. The top may be of alternate strips of wood, glued together to prevent warping, or it may be of iron. In the design shown the lower box is also a foot-step. A steel foot-screw supports the weight and thrust of the bearing. The back of the box is of babbitt-metal. The front is of brass composition, which is slipped in place, and is held by a set-screw through the cap of the box. The spindles always have a vertical adjustment to bring the cutter-knives to the proper level.

The upper end of the spindle ends in a species of chuck (Fig. 491), by which two flat knives of the required shape may be held firmly by the central screws and the set-screws. Many firms are using solid cutters, which can be milled to the required profile, and are not as liable to the dangers which attend the flat knives. If a knife works loose in a spindle revolving at 5,000 revolutions, as these small ones may, the centrifugal force transforms it into a dangerous missile.

Fig. 492 shows a form of one of these solid cutters for edge-molding, and Fig. 493 shows how the cutter is freed between the edges to diminish friction and to give clearance to the cut. The dotted line shows the full

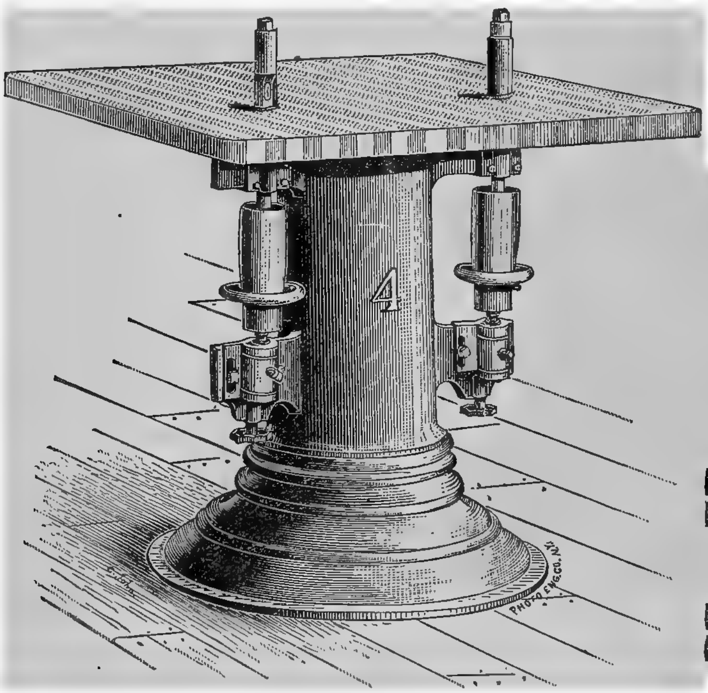


Fig. 490.

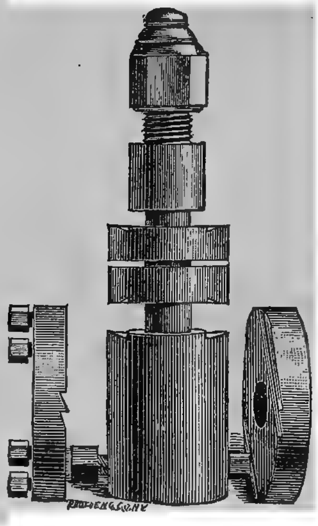


Fig. 491.

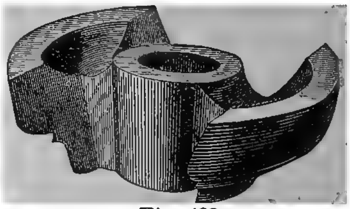


Fig. 492.

circular profile. Cutters of this type cut at all four edges, so that they may be reversed. They are a specialty of one of the carving-machine builders, and are milled from Pittsburgh steel. For the protection of the fingers in the use of the machine a cage or shield may be put over the spindles supported on an adjustable upright.

There are objections to the use of the quarter-twist belt. The spindles must run very rapidly, and since the pulley is small a wide belt is needed to prevent slipping. The counter-shaft, too, must be at some distance from the

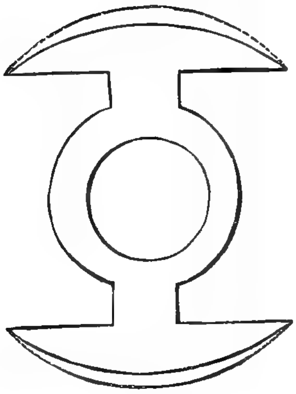


Fig. 493.

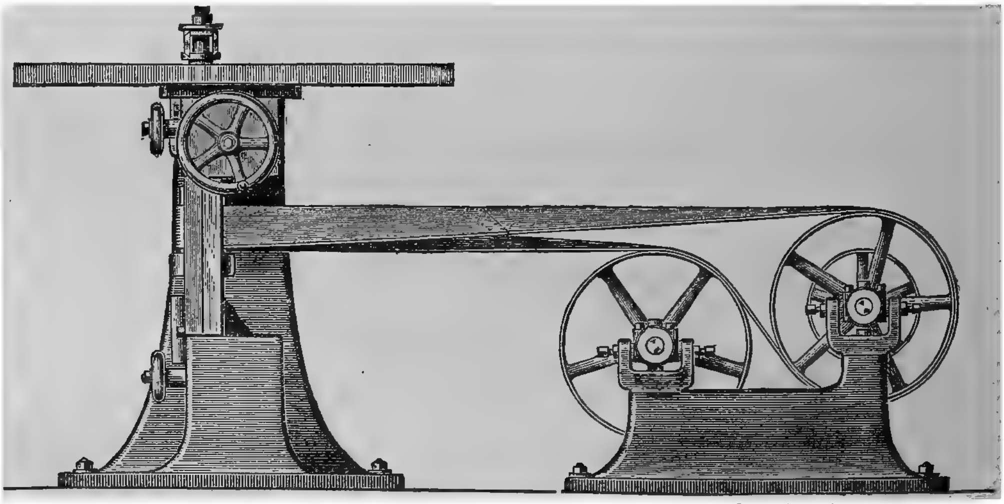


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Fig. 494.

machine, to avoid a very great strain and wear due to the twist in a short interval. The design shown in Fig. 494 in side view and in Fig. 495 in front view exhibits the use of large guide pulleys to cause the belts to approach the spindle-pulleys more nearly at right angles to their axis. The shaft-boxes are adjustable and swivel. The two spindles turn in conical brass journal-boxes, which are borne in a frame gibbed to the base-casting. These frames are adjusted vertically by inclined planes worked by the hand-wheels. The cutter-knives are held by compression from the nut above them.

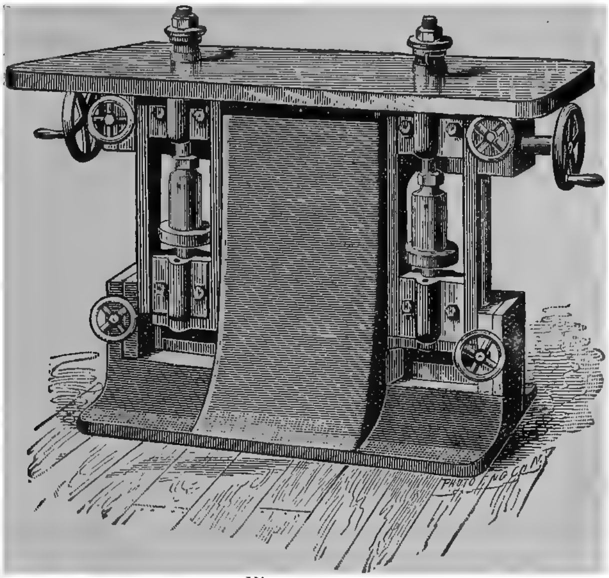

Fig. 495.

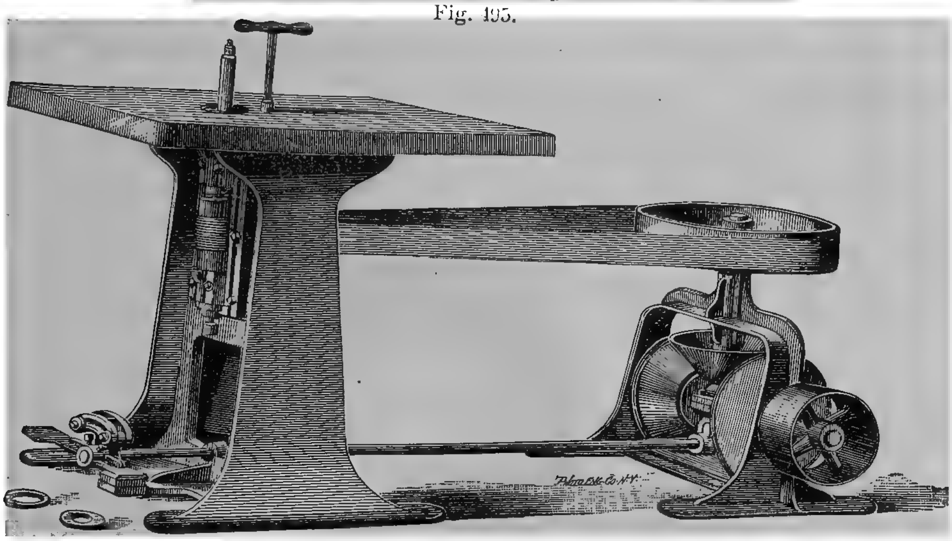

Fig. 496.

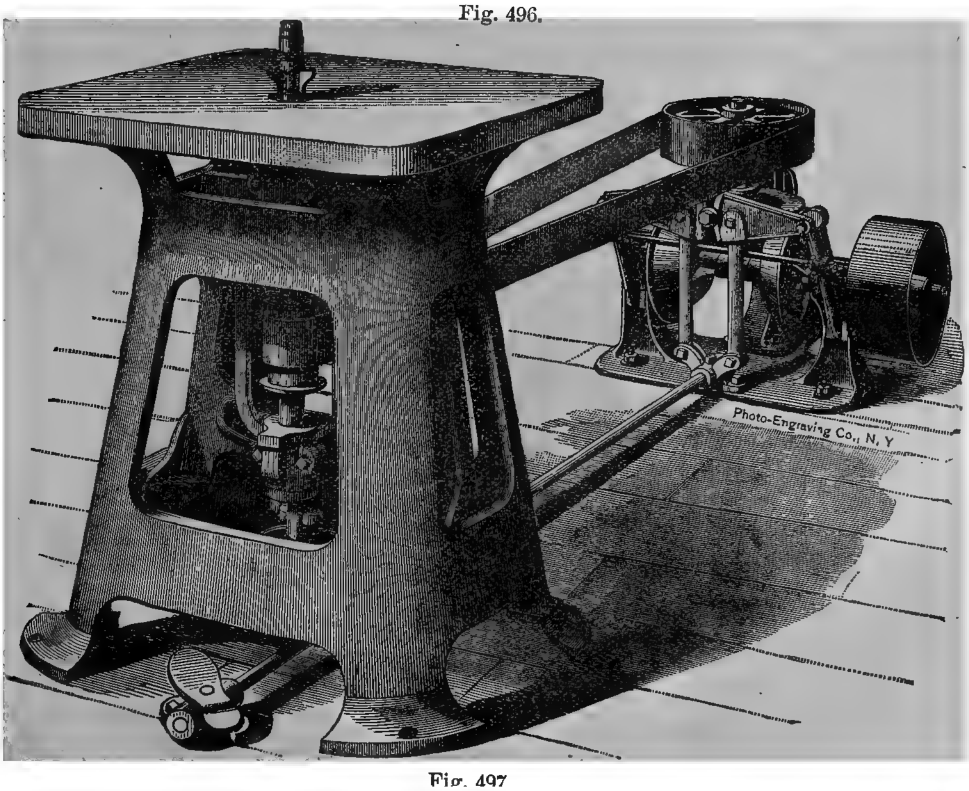

Fig. 497

The western builders have sought by the use of a simple reversing device to secure the advantages of a straight belt and of a single spindle. Fig. 496 shows one of these designs. The loose pulley is dispensed with, and the vertical shaft may be driven by frictional contact with one or the other of the cones on the shaft. The foot-treadle turns the rocking-shaft and shifts the driving-cones into contact with the follower. The latter is an iron wheel; the surfaces of the other two are of paper or of glued tar-board. The spindle-gate is raised and lowered by the socket-wrench. The slides are of dovetail form. The lower bearing consists of a conical box inside of a cylindrical case, with step-screw at the bottom. The friction device of Fig. 497 consists of paper drivers and iron follower, the shifting mechanism having some original features. The cones are shifted by the foot through the torsional shaft, which throws the spiral sectors. They bear upon the roller upon the stud between them, and thus lock the levers. In another design by the same builders the two cones are on the upright shaft, and the reversal and arrest is effected by a rock-shaft, controlled from a handle at the left of the table. The spindle frame is double, of a ribbed section, and the bottom step is made adjustable and self-oiling. The frame has vertical and angular adjustment, for flat and deep moldings.

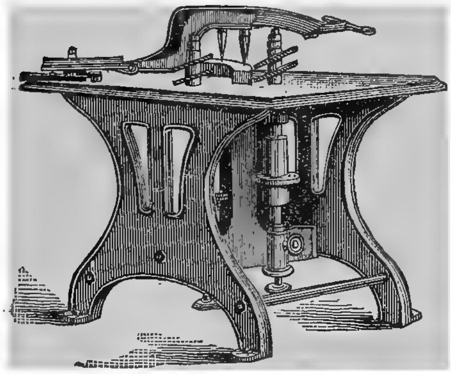

Fig. 498.

Fig. 498 shows a machine for shaping which uses saws set obliquely on the vertical spindles. The fine teeth do not cut or tear, but give a shearing or oblique action, which fits them for working against the grain. The illustration shows how arcs may be produced by the use of a machine of this class. The pointed holders are pivoted around an adjustable center.

Fig. 499.

The machine of Fig. 499, while applicable as a friezer, is especially fitted for carving or for raising panels. The counter-shaft has open and crossed belts, and the spindle-pulley has to have a length greater than the diameter of

its driver to permit the quarter-twist belt to follow its tendencies when the counter-shaft is reversed. The newer machines have three cones, and avoid the twist. The work to be carved or paneled is secured to a former or templet, which is guided by the pin in the bottom of the pressure-plate on the upper spindle. This plate acts as a platen to resist the lifting action of the cutters. It is adjustable for thicknesses. The upper box of the spindle is babbitted; the lower journal has a brass box, with steel washer and step-screw. The feed of the cutter to its work is given by the foot-treadle, adjusted by the screw at the side, with suitable stops when the right depth

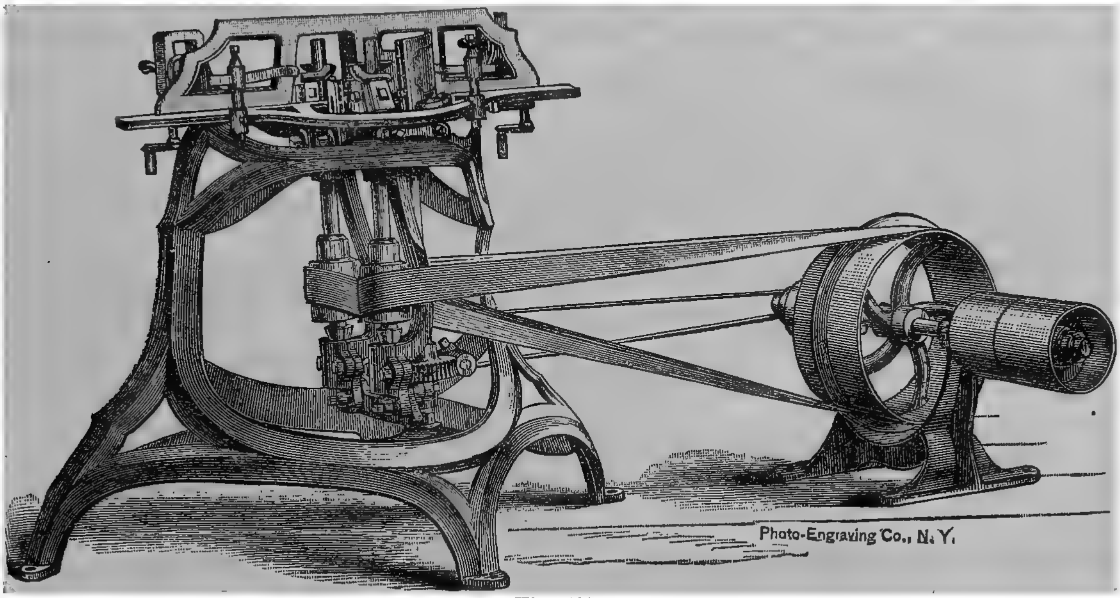

Fig. 500.

is reached. Upon the top of the table special attachments may be bolted for elliptica. molding and for bracket-molding. It is in this latter function that this tool finds a field to replace the jig-saw. A rotary mill replaces the platen, and is driven over guide-pulleys on the back from the counter-shaft. A tool of the type just described is the only one which can sink panels. For raising panels in relief the usual type of machine is shown by Figs. 500 and 501. There are two vertical spindles, one on each side of a guiding-fence. By the two spindles both sides

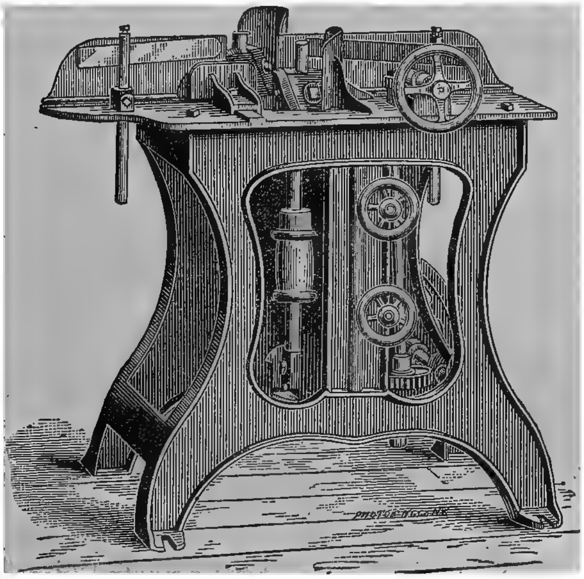

Fig. 501.

of stock may have panels raised on them or intricacies of grain may be provided for. The spindles are fitted with knives to produce a helical or dragging cut, and any profile for the edge of the panel may be secured by properly-shaped knives. The spindles are adjustable laterally for different thicknesses of panel-bed, and also vertically for different widths of panel. There is also an angular adjustment sidewise. Springs in suitable holders confine the stock to the fence. It is usually fed by hand; power feed-motion may be provided, in the shape of a spirally-corrugated roller in front of the cutters.

Panels may be also raised by the universal or variety wood-worker by the mounting of suitable cutter-heads. Where there may be much of it to be done, it is worth while to mount such cutter-heads separately, in order to avoid the temporary stoppage of the wood-worker in its more usual operations. Fig. 502 shows such a machine, built with a wooden frame. The shield for the cutters is shown detached at the foot of the table. The cutters are held in the head, so as to give an oblique cut, and both sides may be worked at once. Lateral adjustment of the cutter-heads and vertical adjustment of the table are required, and are both provided for. The removable knives render unnecessary what would replace the angular adjustment of the vertical spindles, and in respect to simplicity there would seem many advantages in favor of this latter type.

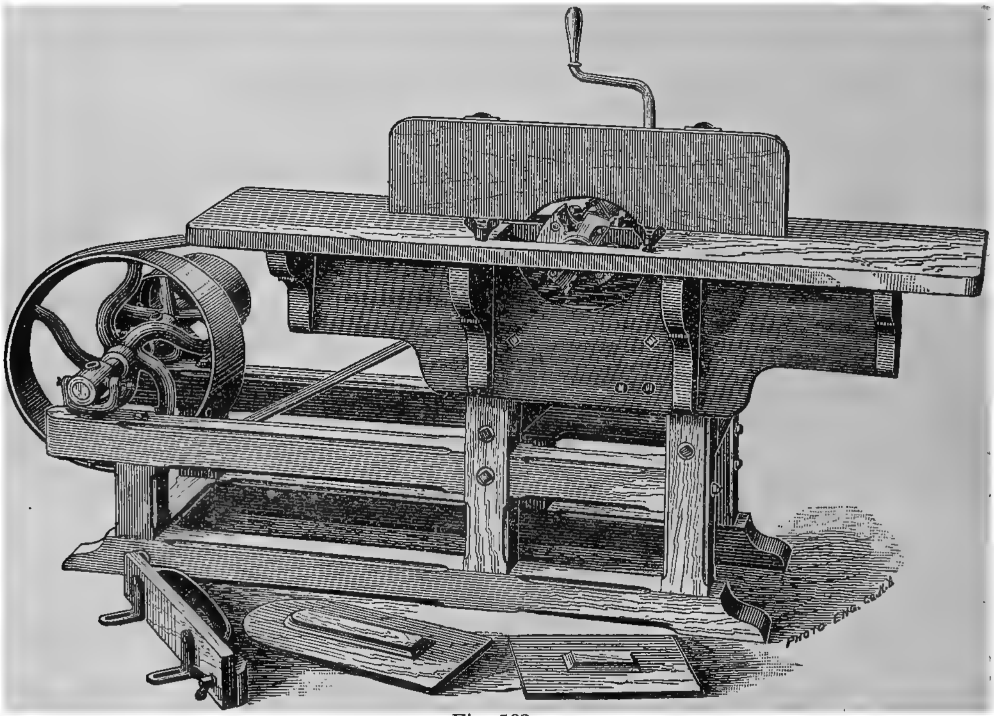

Fig. 502.

The adaptation of the friezer or carver for dovetailing is exceedingly simple. The spindle carries a cutter of the shape shown in Fig. 503, and by varying its size and shape every proportion may be secured for the joints. A simple clamping, feeding, and spacing carriage runs upon ways clamped to the top of the table, and cuts the front and side dovetials at one operation. Fig. 504 shows the attachment for the carver and molder made up into a separate machine, as it is judicious to do where it can be kept full and remunerative. The front and side are clamped in place, and are fed to the cutter by an arm with a sector. The edge of a spring falls into notches to

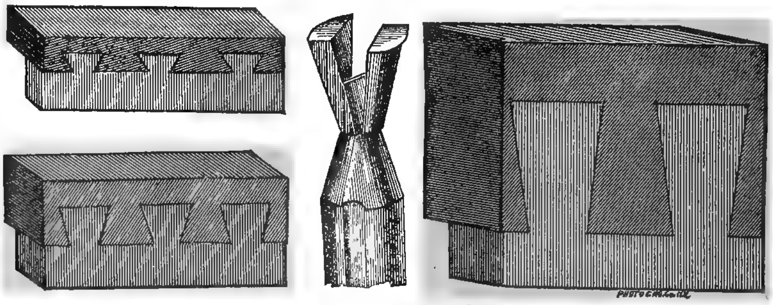

Fig. 503.

give equal spacing. The linear cutter insures the fit of the pins, since the edges of front and side are cut by the same lines. Thicknesses from one-quarter of an inch to $1\frac{1}{2}$ inches may be dovetailed with equal facility. The mechanical features of its construction are the same as in the carver of the same builders. Fig. 505 shows a different from of a similar machine. This form of dovetail is stronger than the Knapp dovetail, with round pins made by a hollow auger, and superior to the Yankee dovetail, where the ends of the sides are left straight without being scalloped.

The radius-planer of Fig. 506 is an edge-molder with horizontal axis. The material to be planed and shaped is clamped to a pattern and presented by hand to the cutters which have the required profile. Such a machine, beside working crooked and cross-grained stuff, can be used as a machine spoke-shave or smoothing-plane for very narrow work. Forming-guides go with the heads of various profile, for cornering, chamfering, and rounding, and the machine may be made useful in many kinds of manufacture.

The tools belonging to this subdivision bear about the same relation to wood-working machinery that milling-tools bear to the metal-working tools. For irregular outlines upon curved shapes they fill a large field, and one of very great importance in wood-conversion by machinery.

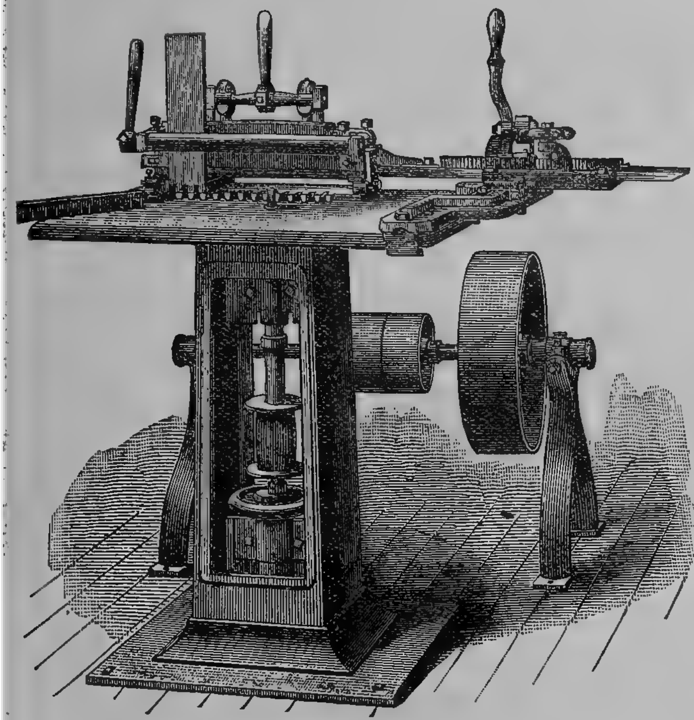

Fig. 504.

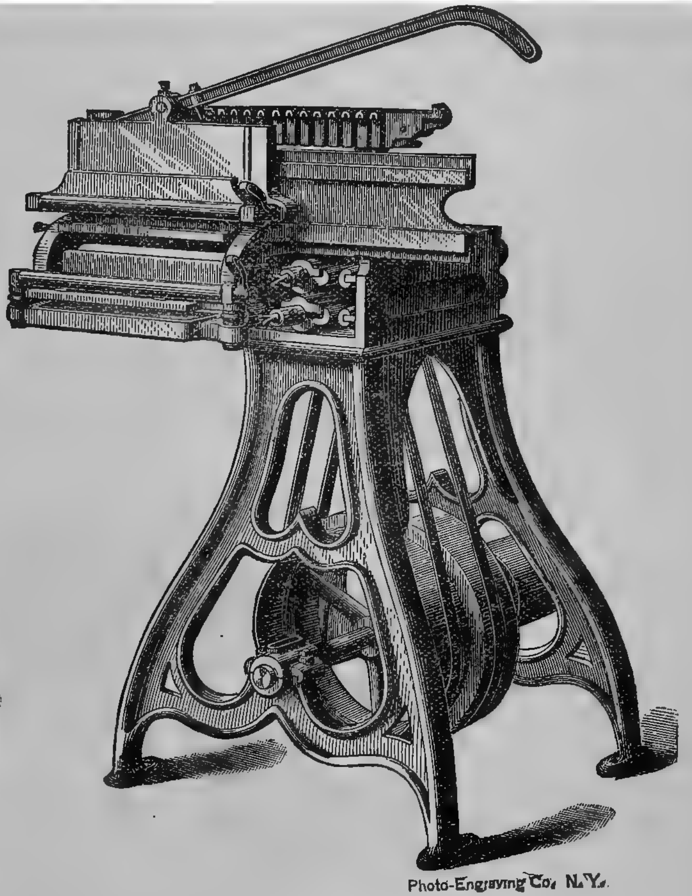

Fig. 505.

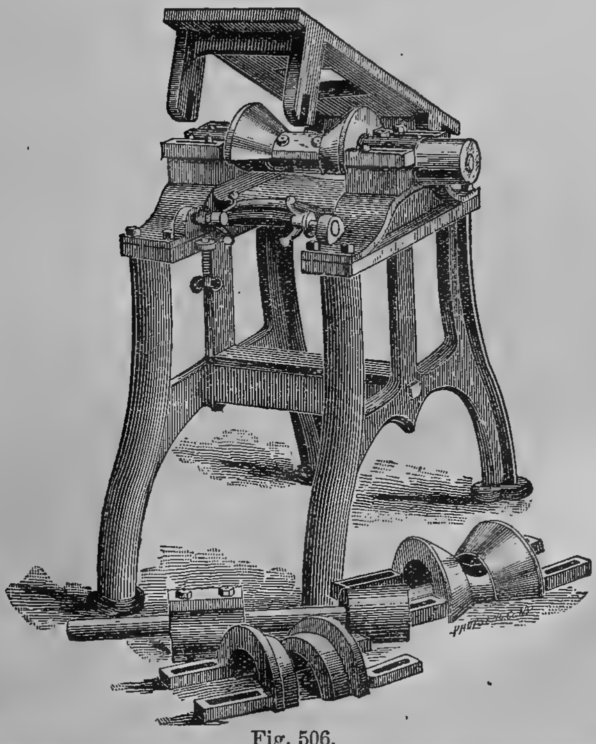

Fig. 506.

§ 51.

H.—TOOLS OPERATING BOTH BY SCISSION AND PARING.

WOOD-LATHES—GAUGE-LATHES—LATHES FOR IRREGULAR FORMS—DOWEL, PIN, AND ROD MACHINES.

Any tool whose cutting action is in a plane transverse to that to which the fibers are parallel must first sever them and then split or pare the severed fibers from the stock. In the paring-tools hitherto discussed at the moment of severing the chips the cutting-edge has been moving parallel to the axis of the material. The feed has been at right angles to the axis, around which the cutter-knives were revolving. In the remaining class the feed will be in a plane parallel to the axis of the cutters, and the latter will act at right angles to the axis of the material. The ordinary wood-lathe illustrates this. The work revolves with its fibers at right angles to the axis of the turning chisel. The latter is fed along the rest parallel to the axis of the cylinder which is being formed. The cutter must first sever, and then split or pare. Its action is therefore a combination of the two previous methods.

With respect to the ordinary wood-turning lathe there is but little to be said. All builders of wood-working machinery make the head- and tail-stocks and rests, leaving the purchaser to furnish the shears, which are very often of wood, with wood or iron legs. Fig. 507 illustrates a typical form. For the convenience of pattern-makers

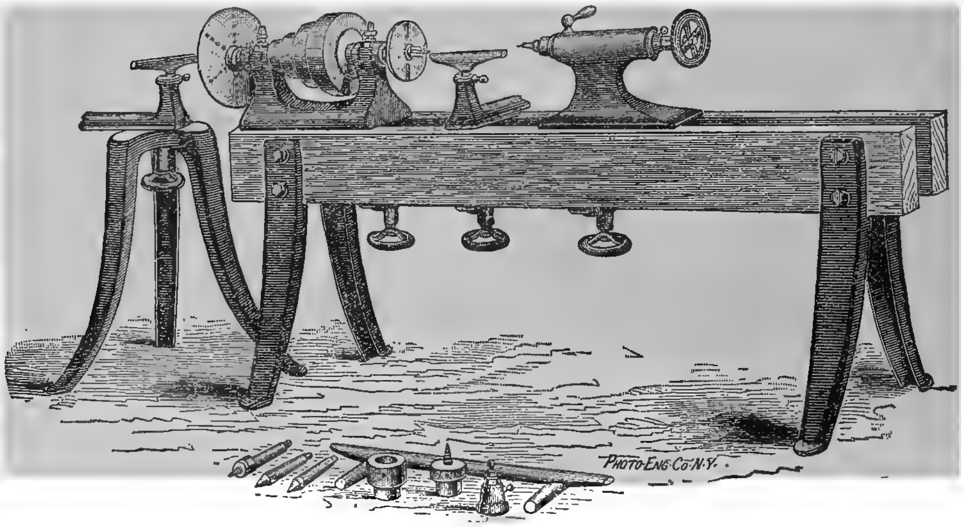

Fig. 507.

who may have large flat surfaces to chuck and turn the outer end of the head-spindle is made to accommodate a large face-plate, and a special tripod holds a second rest for facing large work. The lathe then has a swing equal to the height of its spindle from the floor. When the second rest is on the shears it may help carry the long double rest for long cylinders. The cone-pulleys are very often built up of mahogany for the sake of lightness at their high speed. The figure illustrates screw-clamps for tail-stock and rests. Very often lever cams or wedges are used. It also illustrates the prevailing arrangement of the nest of pulleys, with the largest nearest to the center. Fig. 508 shows an arrangement designed to give more freedom to the swing of long tools when working near the

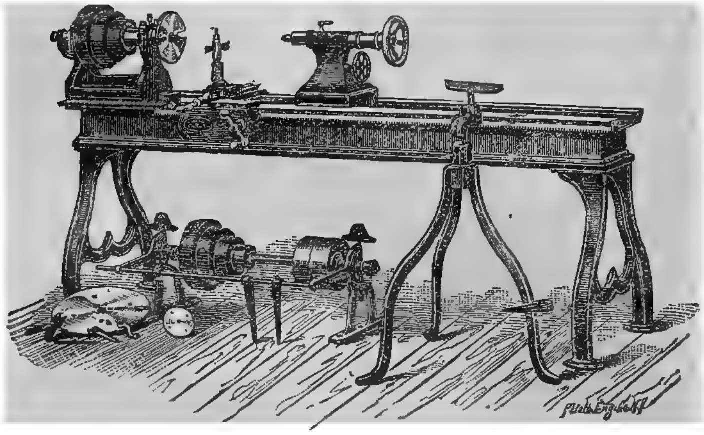

Fig. 508.

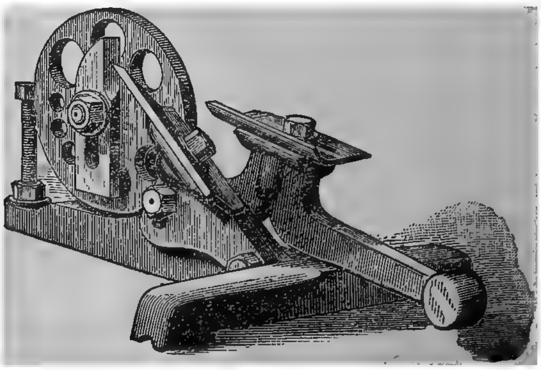

Fig. 509.

head. The cone is reversed, and has its largest pulley farthest from the center. This shows a type of iron bed, and the rest is moved along by rack and pinion. The T-rest may be replaced by a tool-holder, for dimension-turning of true cylinders. The shears have a flat top, and some builders make them solid across the top, with raised ways near the edges. The extra face-plate and tool-rest form part of this lathe also.

So simple is the wood-turning hand-lathe that it scarcely deserves further mention. Its large and varied capacities are due to the skill of the operator who manages it. But where a large number of duplicates are to be turned, a gauge-lathe will be employed. One man can attend to several machines, and all time for calibration and measurement is saved. The tool is held upon a carriage which receives its feed-motion parallel to the axis of the work. The position of the cutter-point is determined by a pattern or former on the lathe-shear. This former is fixed, and a pin or roller, moving over it, is compelled to vary the radii of the surface of revolution being turned. The tool-point is retracted or advanced as compelled by its connection with the pin at the pattern.

Fig. 509 shows a type of carriage to be run on a false shear on any lathe. The cutter is pivoted near the front end of its lever, and the knob on the rear passes over the corrugations of the pattern. The stock is kept from springing from the cut by the concentric disk, drilled with holes of varying diameter. The longitudinal feed may be given in any way, a very simple one being by a knife attached to the slide, which can be adjusted to take the stock at any inclination and generate any spiral or desired feeding speed. More usually these lathes are specially built, and have a screw-feed.

Fig. 510 shows how this may be applied in front of the shears, driven through an intermediate idle shaft with cone-pulleys from the driving-spindle. The feed is disengaged by clasp-nut at the end of a traverse, when the

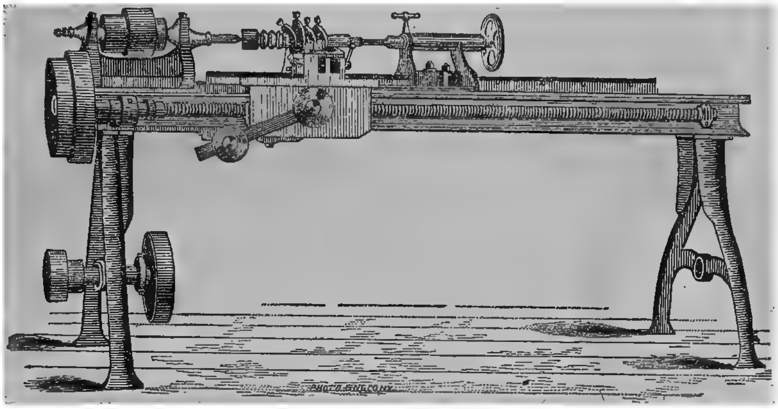

Fig. 510.

carriage strikes stops. The cut shows the use of several tools to distribute the strain of the cut and vary the finish. The pattern also in this lathe is central to the bed, so that no allowance has to be made for the differences in lever-arm of the guide and cutter. Where the pattern is at one side, the profile of its edge cannot be taken directly from the drawing of the finished work. A type of similar lathe, with devices to avoid stopping its motion, is shown by Fig. 511. The stock is guided centrally to the spur-center by the cone. The dead-center is brought up by

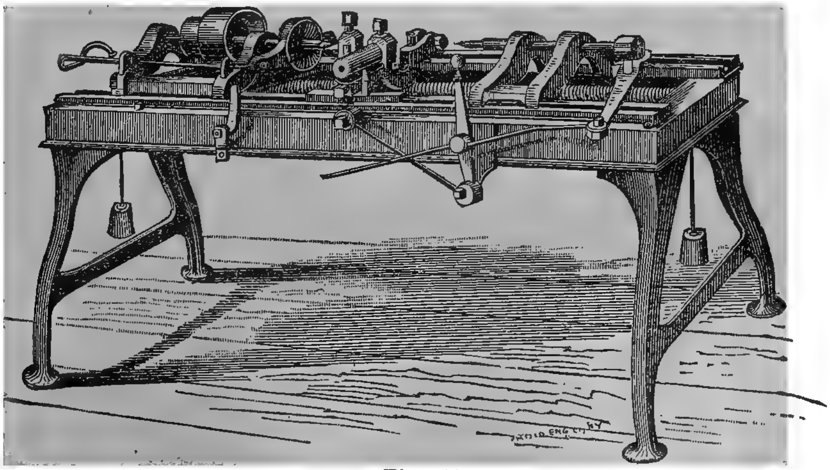

Fig. 511.

leverages and links, so as to save the stops and time required to get to it on long work. The feed-screw is between the shears. The larger and more elaborate gauge-lathes have a roughing-cut taken by a tool-point guided by a former, and finish the surface by the action of a knife which has the required profile.

Fig. 512 illustrates one of these. The carriage has a slide which fits the diagonal way planed upon the frame which holds the knife. The roughing-cut is made by the tool in the holder, guided by the former on the back shear. The knife is brought down behind the first cutter, and completes the work to a true profile. The knife, being set diagonally to the axis of the work, makes a progressive or dragging sort of cut, and cutting-off tools

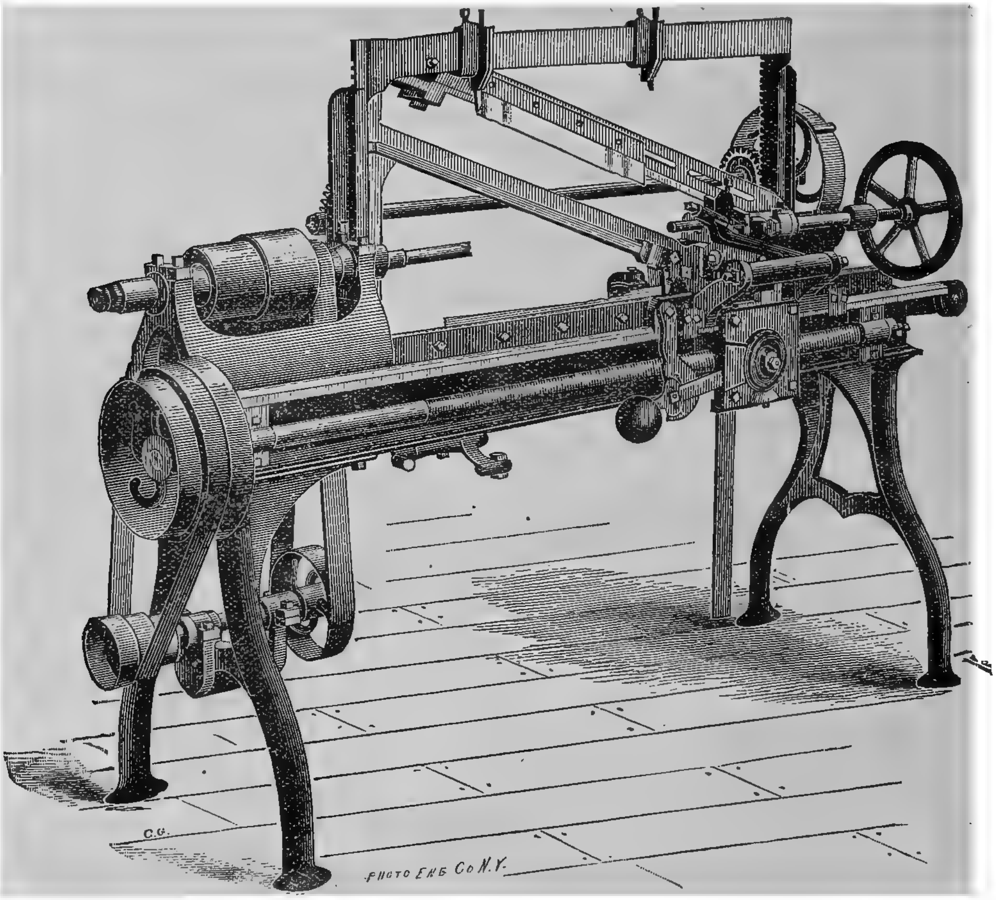

Fig. 512.

may sever the finished from the rough stock. The frame is equalized by racks, into which mesh pinions on the cross-shaft, which is counter-weighted. Stops release the feed, and a weight may draw the carriage back for a fresh piece. The design of Fig. 513 has the finishing-knife formed into a spiral, and brought down to the work by hand. The knife revolves around an axis, and the previous diagonal of a rectangle must become a helix. The

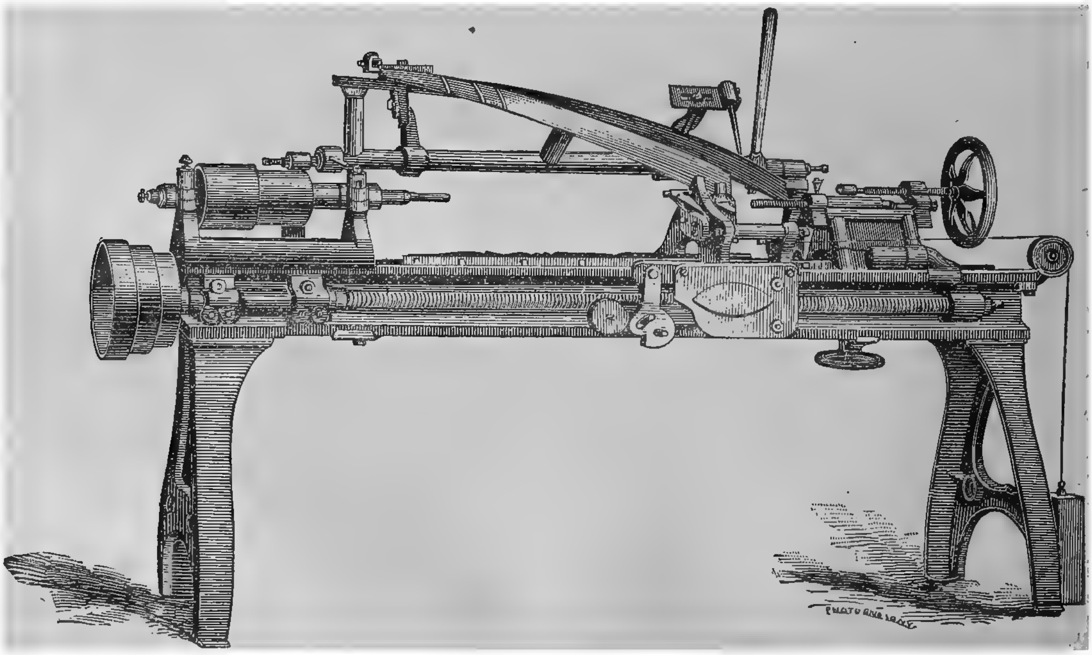

Fig. 513.

same progressive cut is insured, and a smooth, polished, or dead surface may be left, as desired by the operator. The centers of the knife-frame may be taken up for wear. In its other features it resembles the previous design. A ring center-rest, sized to the dimension of the largest part, is attached to the slide of long lathes for slender work. It is claimed for this second form that it is easier to handle in the case of breakage of half-finished work.

The gauge-lathe cannot be conveniently made to produce any but external surfaces of revolution. It is also unnecessarily heavy for a great deal of small work. The Waymouth lathe (Fig. 514) is designed to meet this

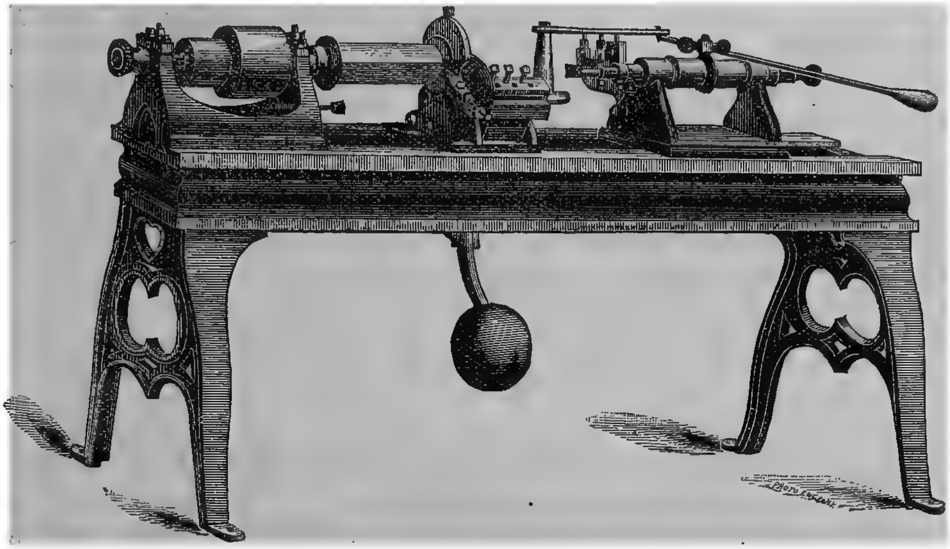

Fig. 514.

necessity, and will bore as well as turn. It is possible with such a lathe to turn 10,000 druggist's boxes in ten hours. The general principle is the successive presentation of properly shaped and located tools by the hand of the operator, or by his knee. These tools are fed up to stops laterally and longitudinally, and must therefore turn out work to standard size at every presentation. The stock is seized by an internal conical screw-chuck, which centers and rotates it. A tapering ring-tool on the carriage sizes and guides the stock, while the tool in the tail-

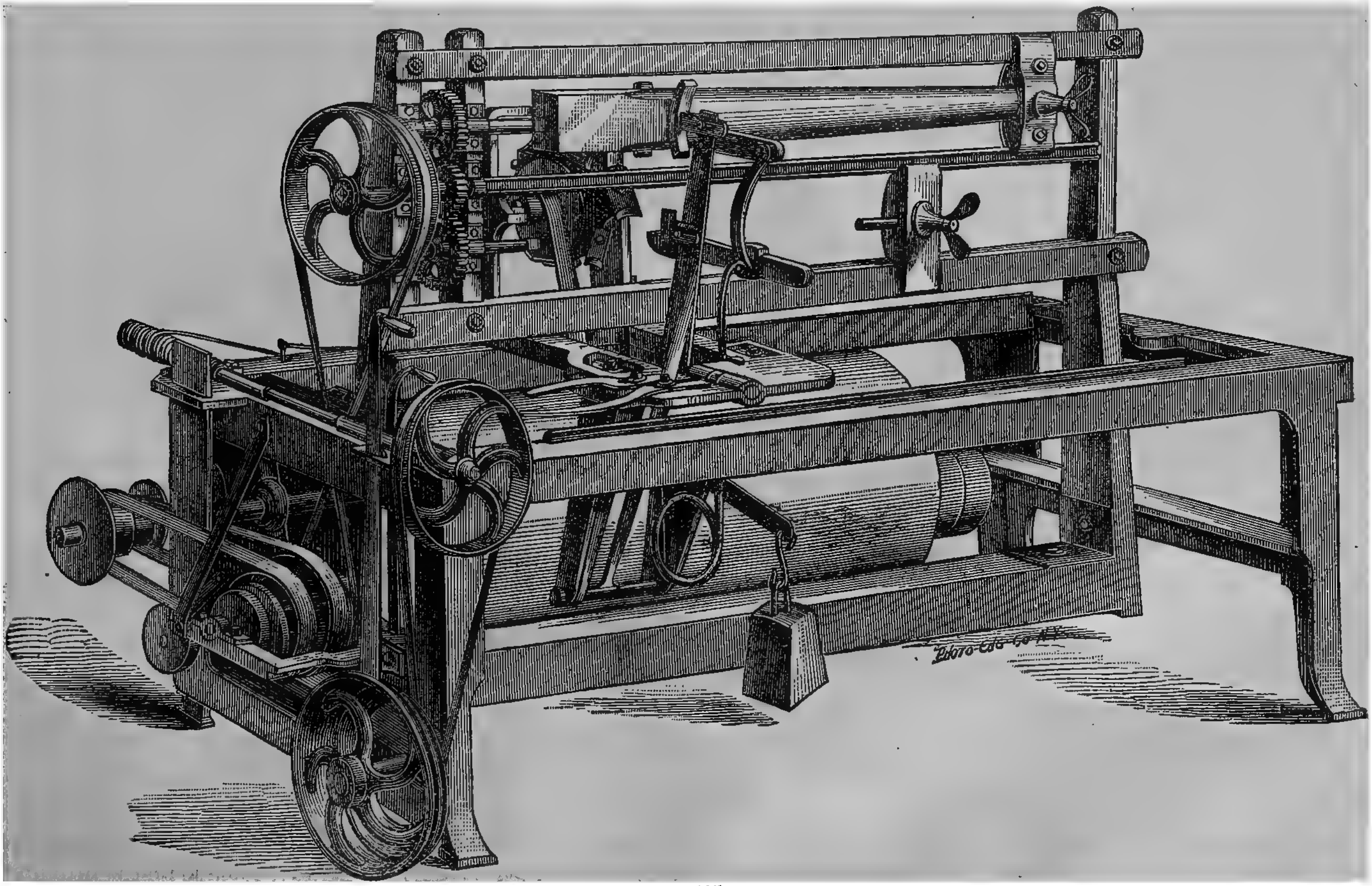

Fig 515.

stock, fed forward by the hand-lever, acts on the end to do what may be there required. Behind the ring-tool is a holder for different special shaping tools. This holder swings toward the work around a hinge-joint near the foot of the carriage. The presentation of the holder is made by pressure of the knee upon the pad on the end of the lever. This lever turns a wrist-plate by a pin. A second wrist-pin throws forward the series of tools on the finishing-rest by a connecting-rod. This latter pin is so arranged that the tools in the holder can only be moved forward the required distance. Any further pressure retracts the tools, because the pin has passed its center. The circumference of the wrist-plate is toothed, and further pressure on the pad feeds up a cutting-off tool by a rack from below. The carriage and tail-stock are gibbed to the inside of the shears. This type of lathe is an exceedingly ingenious device for multiplying the capacities of the machine many fold. While hand-labor is retained to work the tools, yet the element of inaccuracy is eliminated, and all necessity for calibration disappears. Many classes of work could not be so well done by any other machine.

The term lathe might be restricted to those machines which produce volumes of revolution, as in the preceding examples. The name is often extended to cover a class of tools for the reduplication of irregular forms, such as gun-stocks, wheel-spokes, and handles for axes and picks. These are often called Blanchard lathes from the original patentee, whose patent dates from 1819. In their general features they consist of rotating cutters secured to a head. Some of them are roughing-cutters, and others for finishing. The former lead the latter, so that the work may be finished at one traverse of the cutter-head along the stock. The pattern and blank are borne in a frame pivoted below. This frame is controlled in its horizontal motion by an arm on the cutter-carriage bearing a friction-roller which rests against the pattern or former. The stock to be turned is held on centers parallel to the pattern, and the cutters are permitted to remove chips only so far inward as the pattern will permit. The pattern and the blank are slowly revolved, and the former is exactly reproduced. The older type of the lathe, which has advantages for certain duties, is shown by Fig. 515. The frame holding the pattern and blank is stationary endwise, and the carriage carrying the revolving cutters traverses along it. The long drum below drives the cutter-head, wherever it may be. The pattern is above the blank, and has to be larger, of course, than the finished article, which is centered nearer to the center of motion of the forming-lever. The blank and pattern are revolved at a speed of 60 or 80 turns per minute by the train of gears driven by belt from the cone-pulleys. The traverse of the carriage is effected by flexible connection, actuated by belt or by a worm device. The pressure upon the pattern and from the back-rest may be controlled by spring or by weight, or by both. The retreat of the frame at enlargements of the patterns is insured by the pressure on the front side. The feed is disengaged at the end of the traverse by the dogs on the carriage. In place of the wing-nut for adjusting the lower dead-center, a cam-lever may be used. The drum is sometimes mounted separate from the frame of the tool with advantage. Two hand-levers control the motion of the blank and the feed of the carriage and cutter-head.

Another form of the Blanchard lathe is shown by Fig. 516. The blank and pattern are centered upon uprights bolted solidly on a carriage, and the latter receives the traverse motion in front of the stationary cutter-frame. The

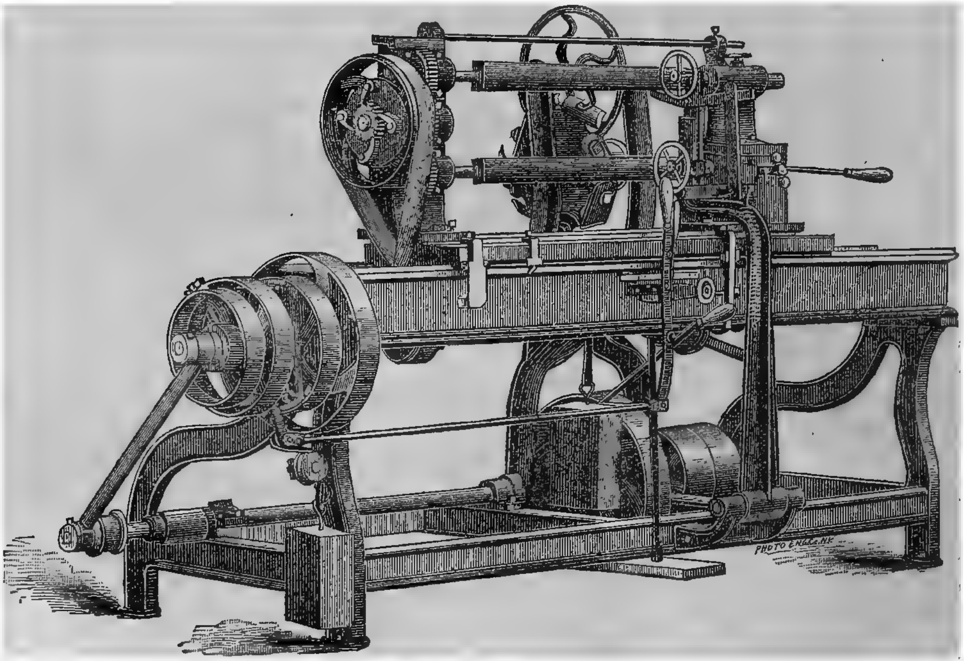

Fig. 516.

use of a long drum is thereby avoided. The yielding for variations of profile is given by the cutter-frame and not by that which holds the work. The cutter-frame is kept to its work by a weight, and a spring-back rest is provided

to keep the blank from flexure. Dogs on the carriage disengage the feed at the ends of the traverse. The wheel which turns the blank and pattern is connected to the gears by ratchet and pawls. The inconvenience of revolving the blank when running backward is thus avoided.

Fig. 517 shows a lathe with drum overhead and traveling cutter-carriage. The latter moves on rollers, and is made heavy to resist the jar of the cutter-head, which revolves at 8,000 feet per minute at the circumference.

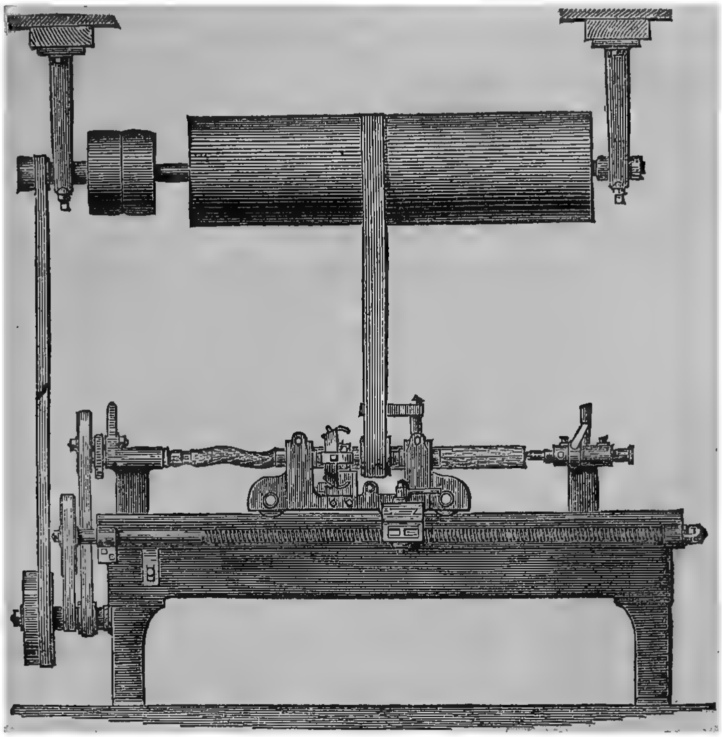

Fig. 517.

The feed is by the bed-screw, and is made variable by change-pulleys at the head. The pattern lies in the same plane as the blank, of which it is an exact duplicate. The same feature of exact duplication of form is obtained by the design of Fig. 518. The cutter-frame is fixed, and the holders turn on an axis as in the preceding design. The rotation of the blanks is given from the drum at the back, and the carrier-frame traverses horizontally. The

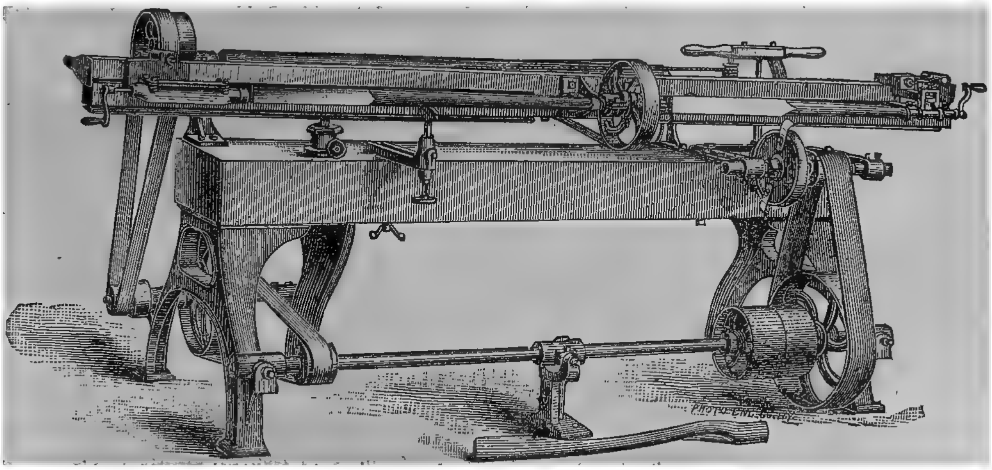

Fig. 518.

tilting carrier-frame is adjustable vertically for different diameters of work. The stops are automatic, as are the feed-motions. Saws may be used instead of cutter-heads if better adapted for the wood or the shape. These tools have been so long and so well known that extended reference to their capabilities would be superfluous. The improvements of latter years have been in details of construction to keep pace with the march of mechanical progress.

Akin to the action of lathes (although inverted) is the action of rod, pin, or dowel machines, such as Fig. 519 *a*. The stock is fed in by hand, and is shaped by the revolving knives. The slope of the knives draws the work inward toward the cutter.

Fig. 519 *b* shows a chuck or holder for steadying the work, and preventing it from turning in the hands of the operator. The machine is exceedingly simple, and is of very great service in many shops. Power-feed machines upon standards are also made.

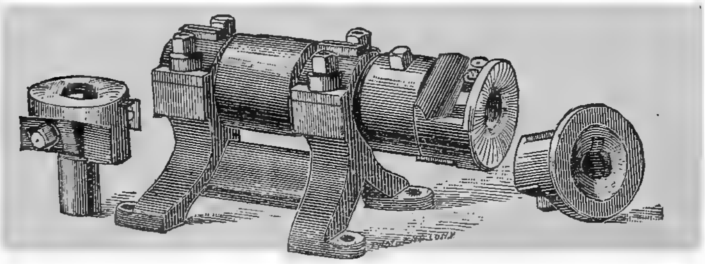

Fig. 519 *a*.

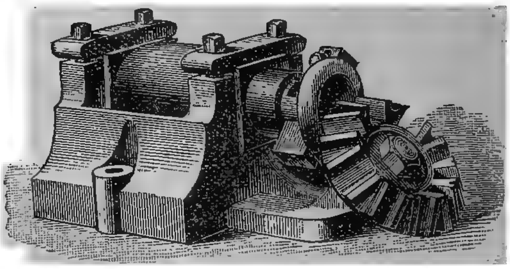

Fig. 519 *b*.

Akin also to the lathes in their action on the lumber are the spiral veneer-cutting machines of which Fig. 520 is a type. The log revolves slowly in front of a stationary knife, which advances by the thickness of the sheet at each revolution. All loss from dust and saw-kerf is thus avoided.

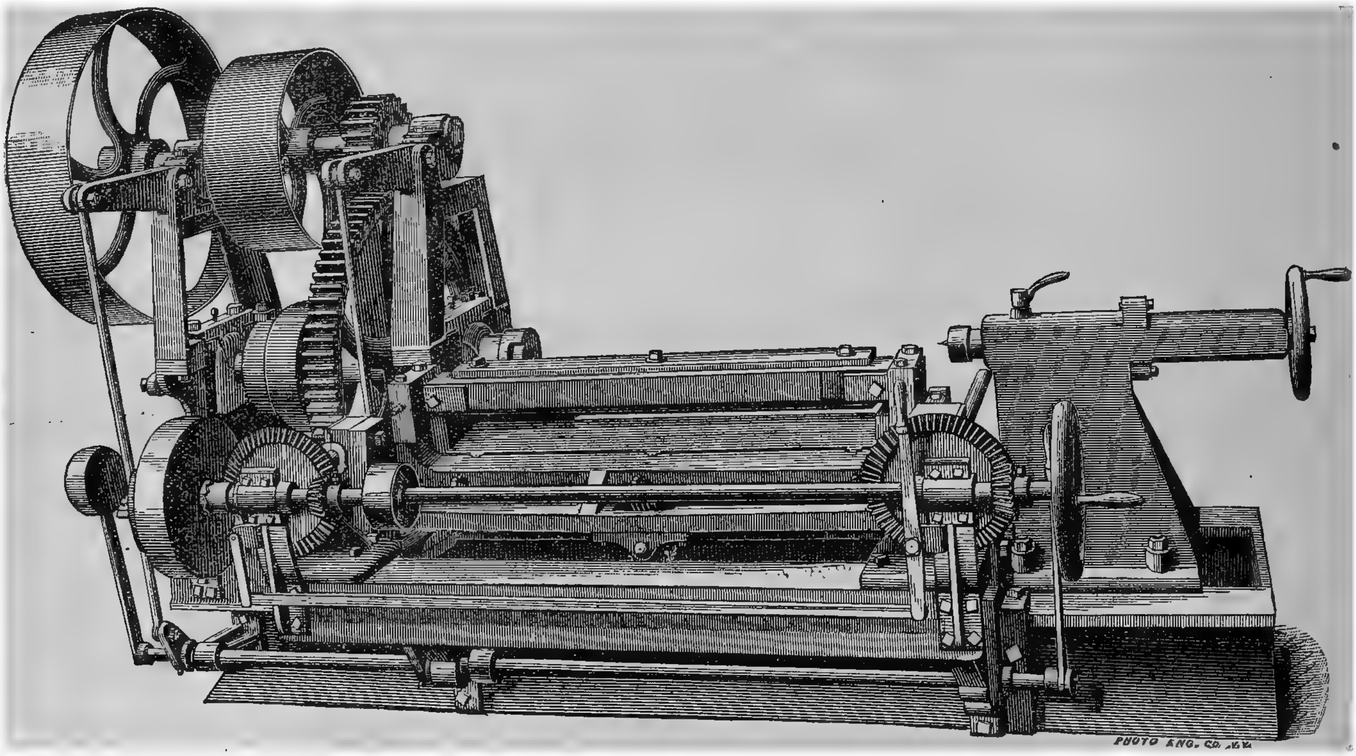

Fig. 520.

§ 52.

TENONING-MACHINES—GAINING-MACHINES.

The joint by tenon and mortise is of primary importance in wooden constructions. Machines for making the parts of the joint will be of wide application in car, carriage, pattern, and bridge shops. The tenon is made upon the end of the piece. A rotating cutter will, therefore, sever the fibers and split them off for the required distance. The severing of the fibers will be done either by sections of saw-plate, or by spurs on the chisel edges of the paring-cutters. The cutters are often arranged spirally, so as to produce a dragging cut, and more in the direction of the fibers. The work is fed to the cutters in the smaller and medium sizes; in the larger designs the cutters may move toward the lumber. This latter arrangement is specially applicable to the machines for double tenons.

In the series of designs of which Fig. 521 is a type, the framing is mostly of wood, with some parts of iron. The lower head is stationary. The height of the lower shoulder is varied by raising or lowering the carriage-ways by the inclined planes operated by the hand-crank. The thickness of the tenon is varied by the rise and fall of the upper cross-frame, which is pivoted at the upright at the rear. The tilt of this frame is controlled by the screw-

and hand-crank in front. The bearings of the upper cutter are adjustable longitudinally to permit the upper shoulder to be offset from the line of the lower, if desired. The two cutter-heads revolve in opposite directions so as not to tend to twist the stock. This latter is held and steadied on the carriage by the foot upon the adjustable hand-lever. But one belt is used. It passes from the driving-pulley below up over the upper head, thence down

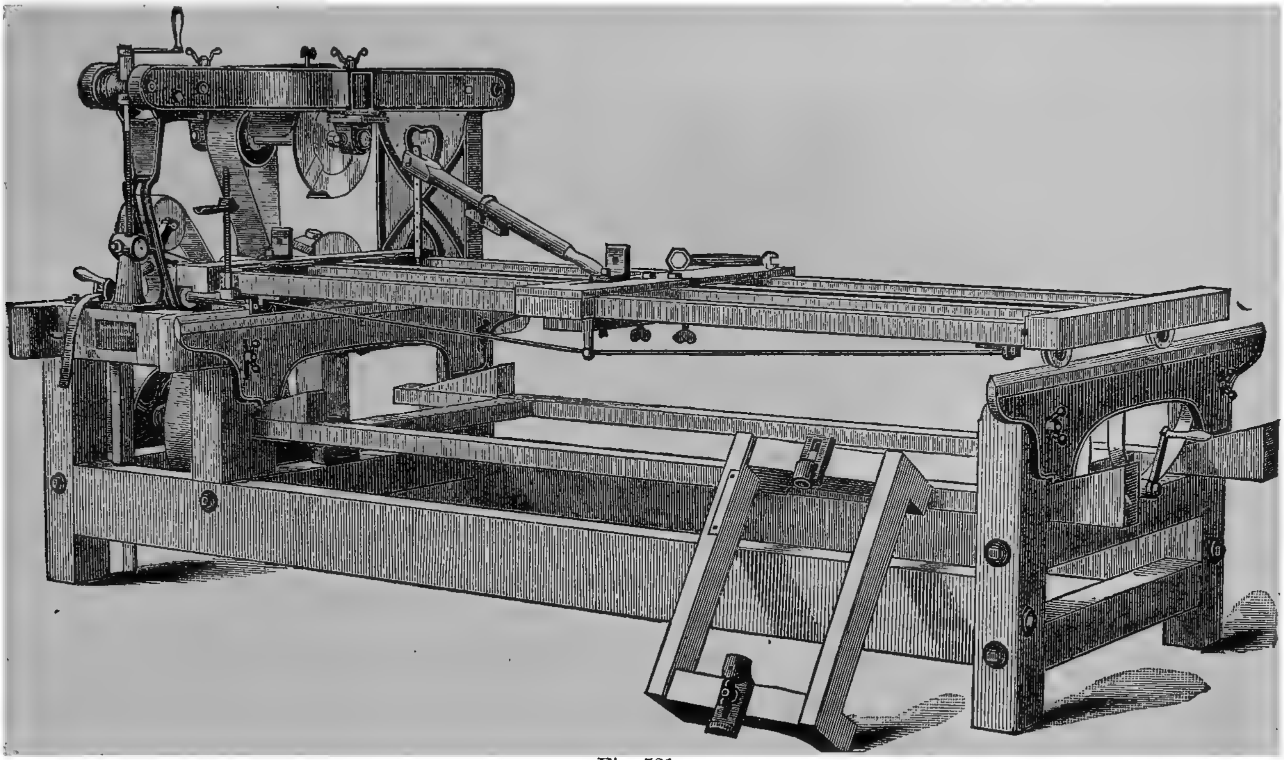

Fig. 521.

under the lower head and upward over a tightener and guide-pulley to complete the circuit to the driving-pulley below again. By this means the cutter-pulleys have the belt around half their circumference, and variation in the thickness of tenon is compensated for. In the form shown the tightener is on an upright, and a flexible thong is clamped to maintain the due tension. Fig. 522 shows a wood-frame machine, with the addition of cope-heads for

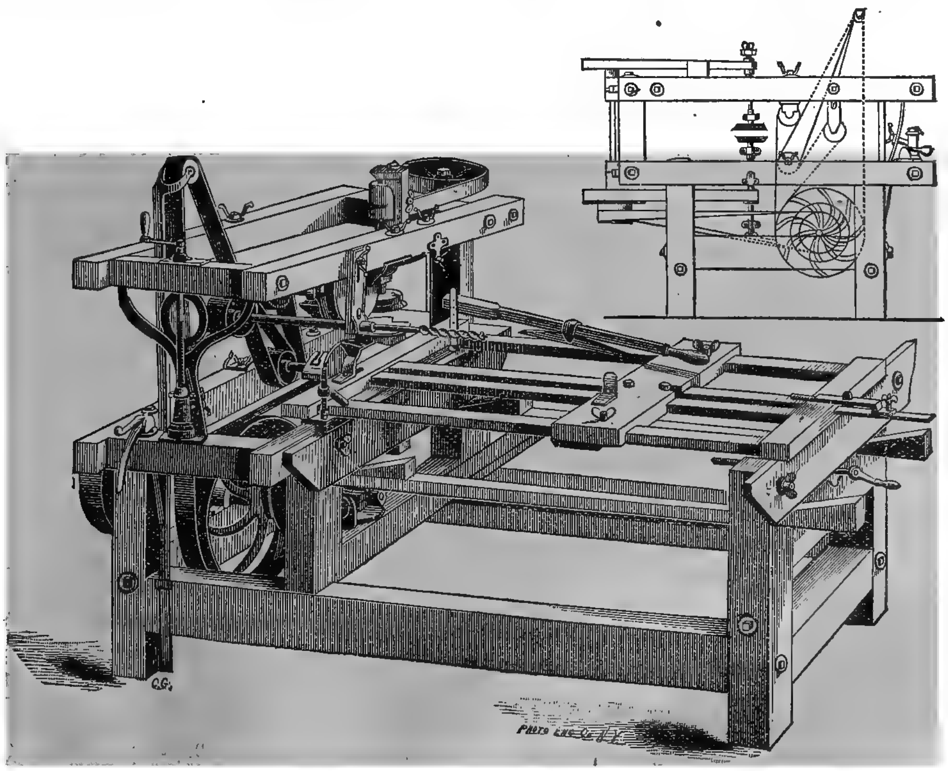

Fig. 522.

profiling the shoulders of the tenon. They are on vertical axes, as shown in the skeleton front view, driven from a counter-shaft at the end. The tightener-pulley stands higher, strained in the same way, and an adjustable boring attachment may be applied, if desired. The cope counter-shaft is driven by a quarter-twist belt from the lower shaft. The design of Fig. 523 illustrates a type of framing partly of iron and partly of wood. The table guiding the carriage has no adjustment, since all required motions are given to the cutter-heads. The frame carrying the lower head is raised and lowered, for the variation in lower shoulder, by a screw turned by the larger hand-wheel. The

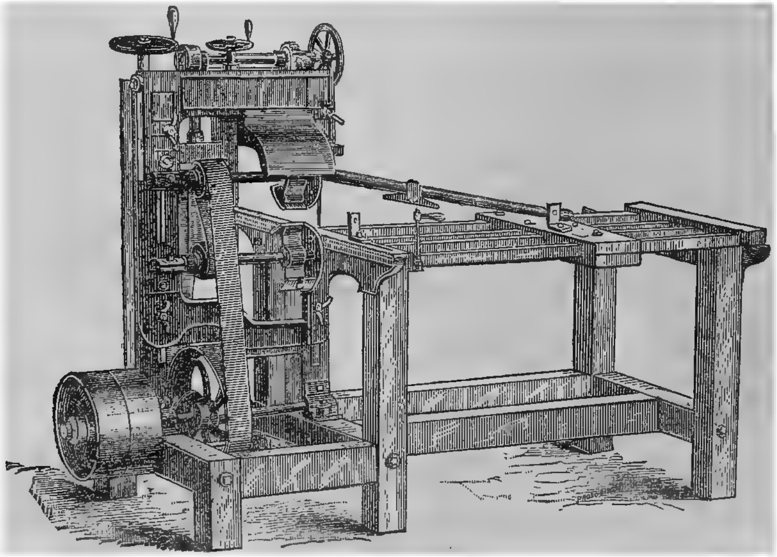

Fig. 523.

frame of the upper cutter is faced to the frame of the lower, and adjusts to the latter by the smaller hand-wheel. By this method both cutter-heads may be moved up or down without changing their relative positions to each other. The shoulders may be varied, therefore, without change in the tenon, or the tenon may be changed without altering

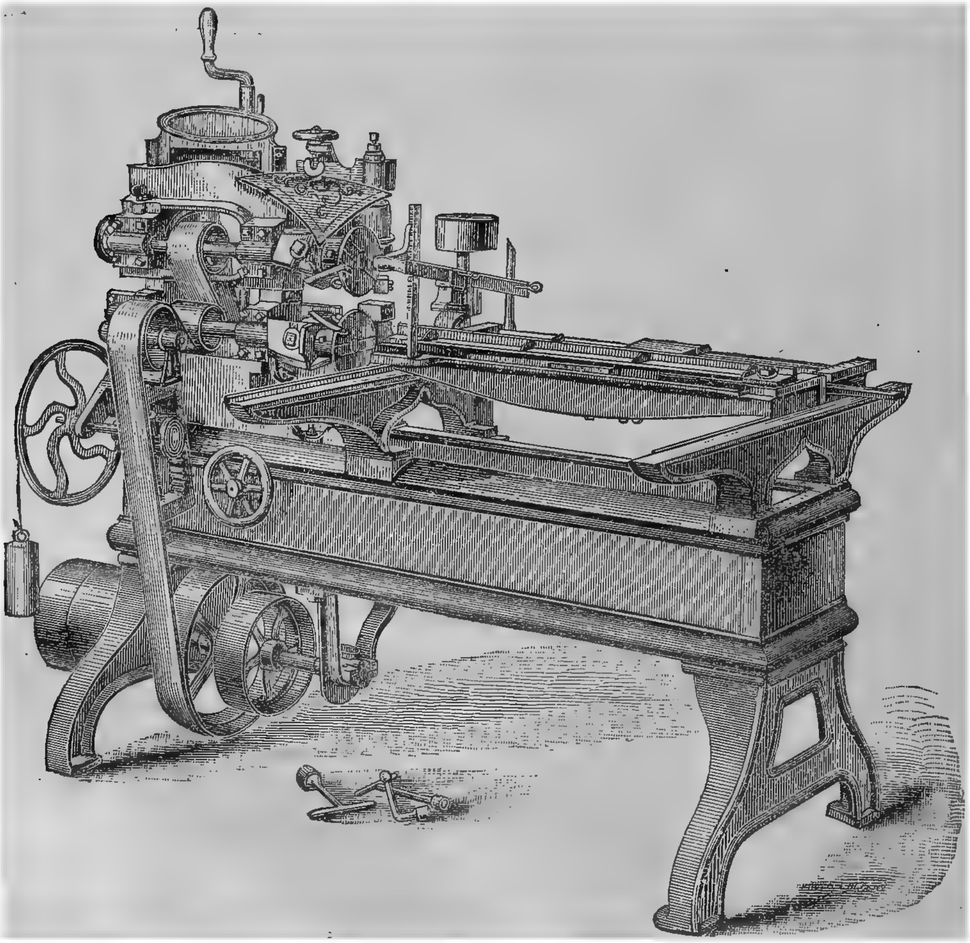

Fig. 524.

the lower shoulder. The upper boxes may be moved to offset the shoulders. The tightener is adjusted by a ratchet and pawl shaft turned by the hand-wheel. The front string piece on the table is of iron, guiding the end next the cutters and permitting increased depth of shoulder to be cut on the lumber.

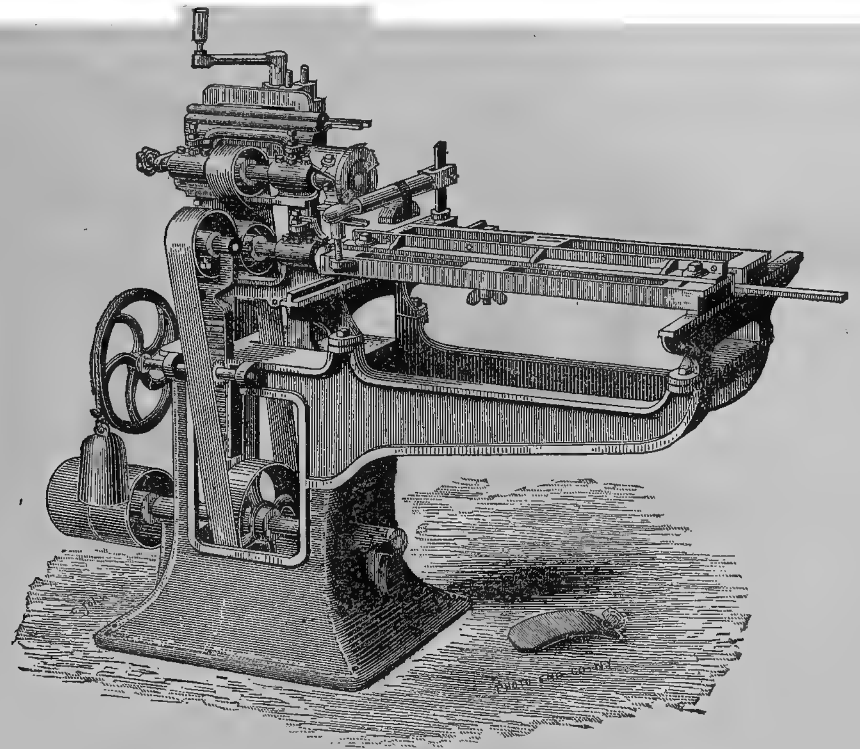

Fig. 525.

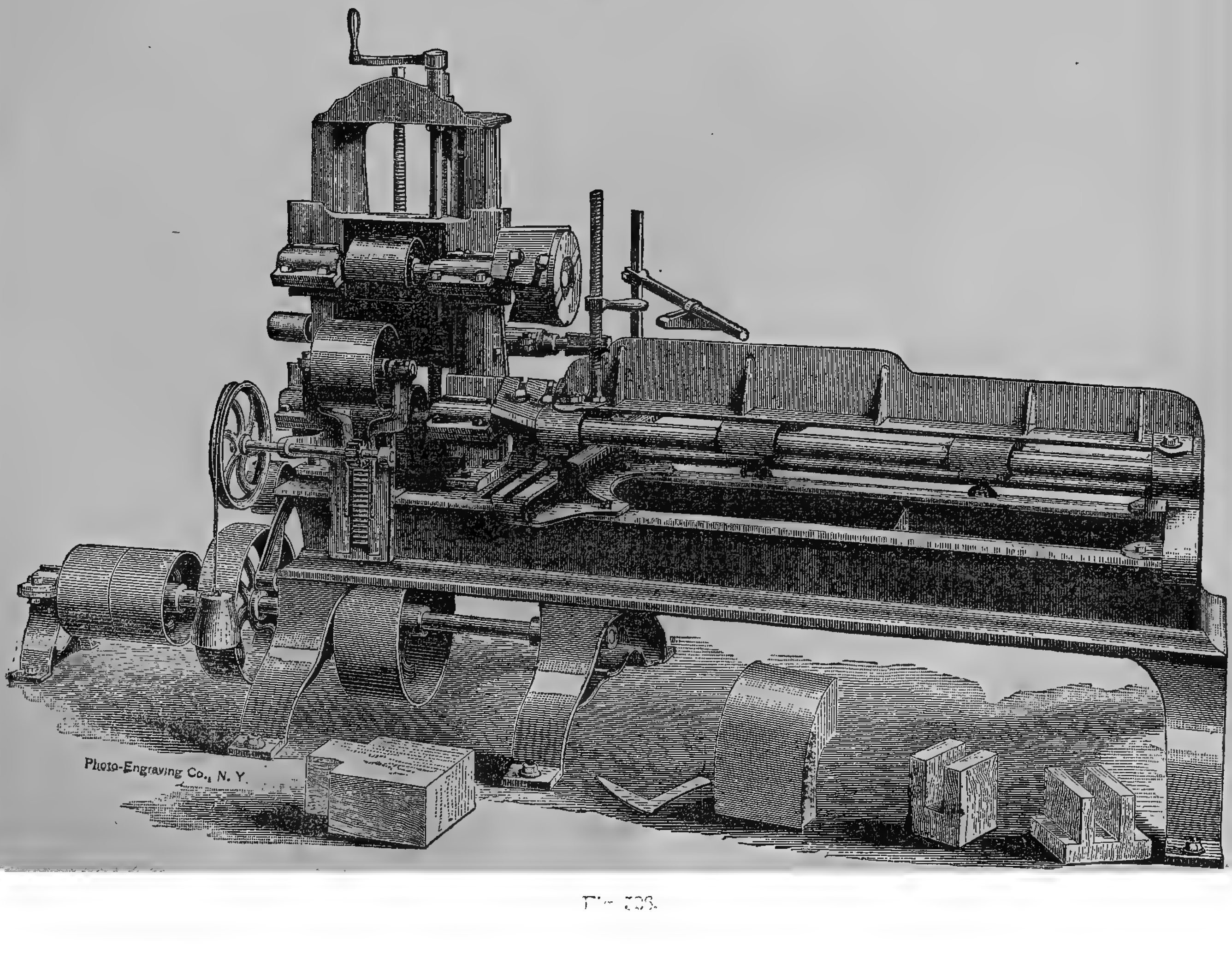

Fig. 526.

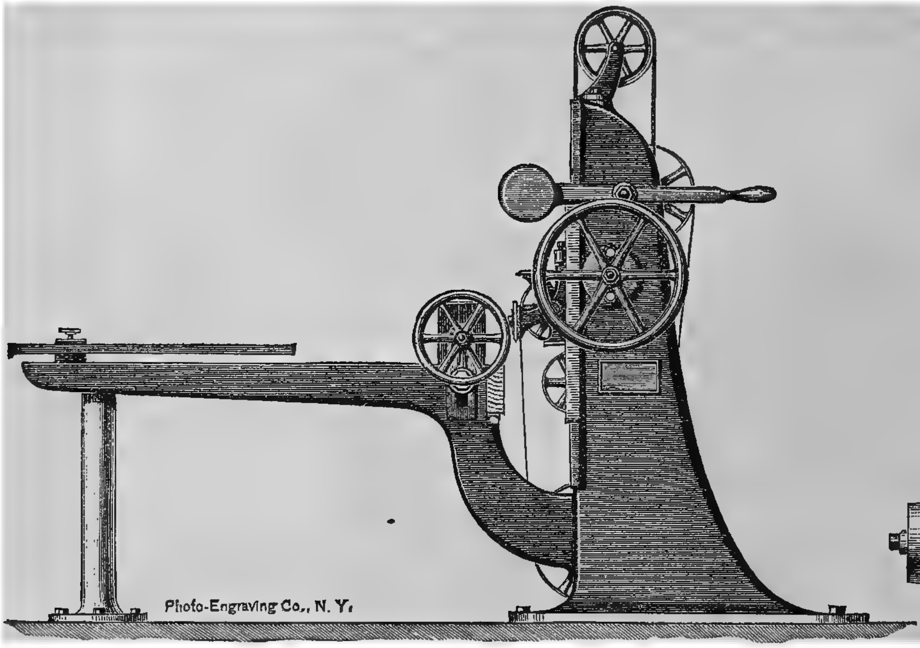

Fig. 527 *a*.

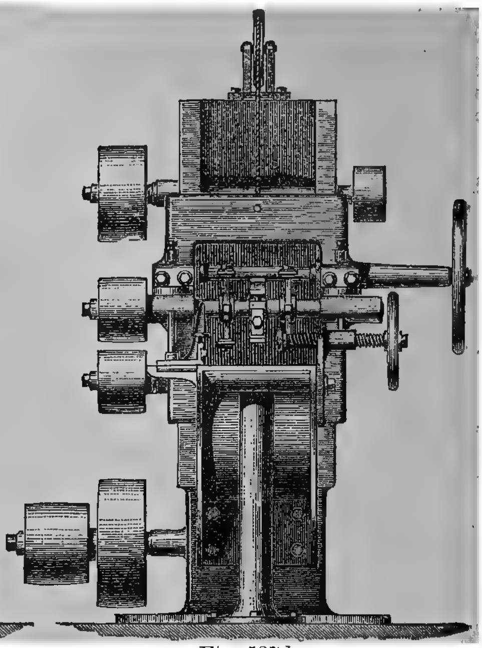

Fig. 527 *b*.

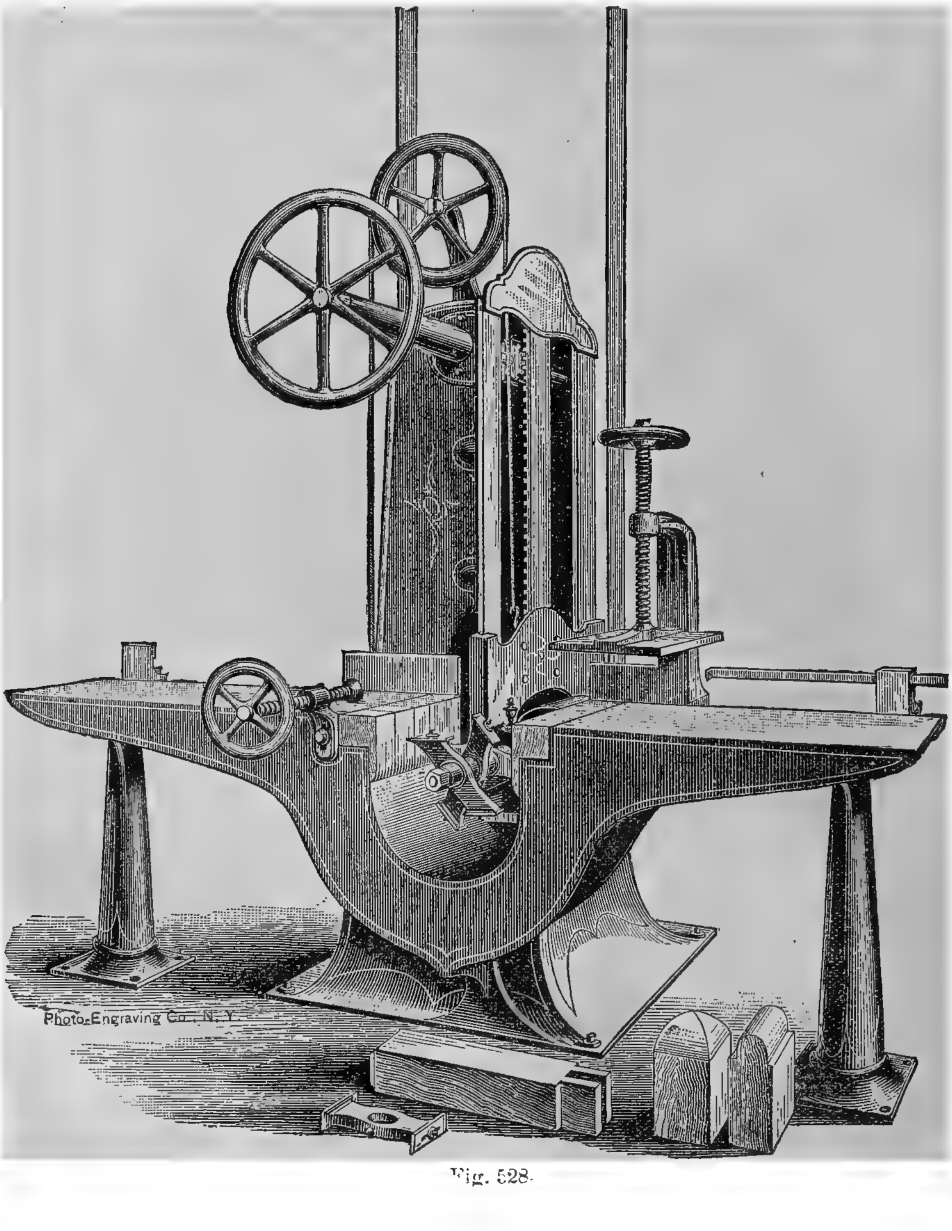

Fig. 528.

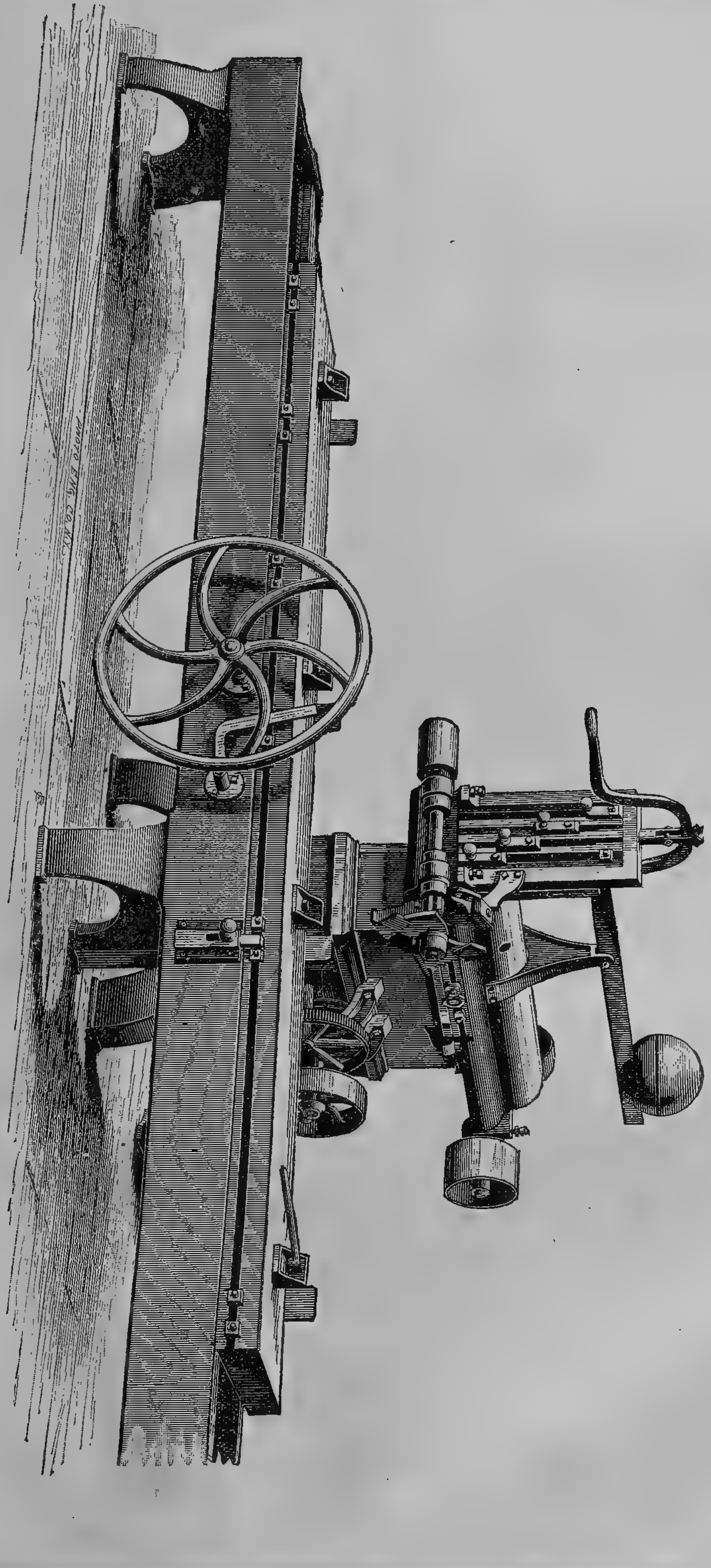

Fig. 529.

Fig. 524 shows the average size of iron-frame machine, with adjustment of the heads upon slides. The binder-pulley is counter-weighted in the simple manner which is usual in the newer tools. The holder of the roller has a rack cut on it. On the axis of a pinion which meshes into it is a larger grooved wheel, round whose circumference is wound a wire rope sustaining a weight. By the gain of leverage a light weight is competent to strain the belt.

Fig. 525 shows a new standard machine for cabinet- and spoke-work. While the cutters on the sizes hitherto have been known as 8-inch heads, those on this machine are but 5 inches, so that higher speed may produce smooth work. The especial feature of this design is the use of gibs under the slides of the table, so that by no possible overweighting or lack of balance can the table be thrown into the cutter-heads. The adjusting-screws for the heads are conveniently geared so that they may be moved together or separately. The upper spindle-boxes move in dovetail slides by the hand-wheel at the tail for offsetting the shoulders. The machine of **Fig.** 526 is the size adapted for car and other heavy work. The two ends of the long table are compelled to move together without binding on the ways by pinions on a shaft, which mesh into racks under the ways. These also prevent the table

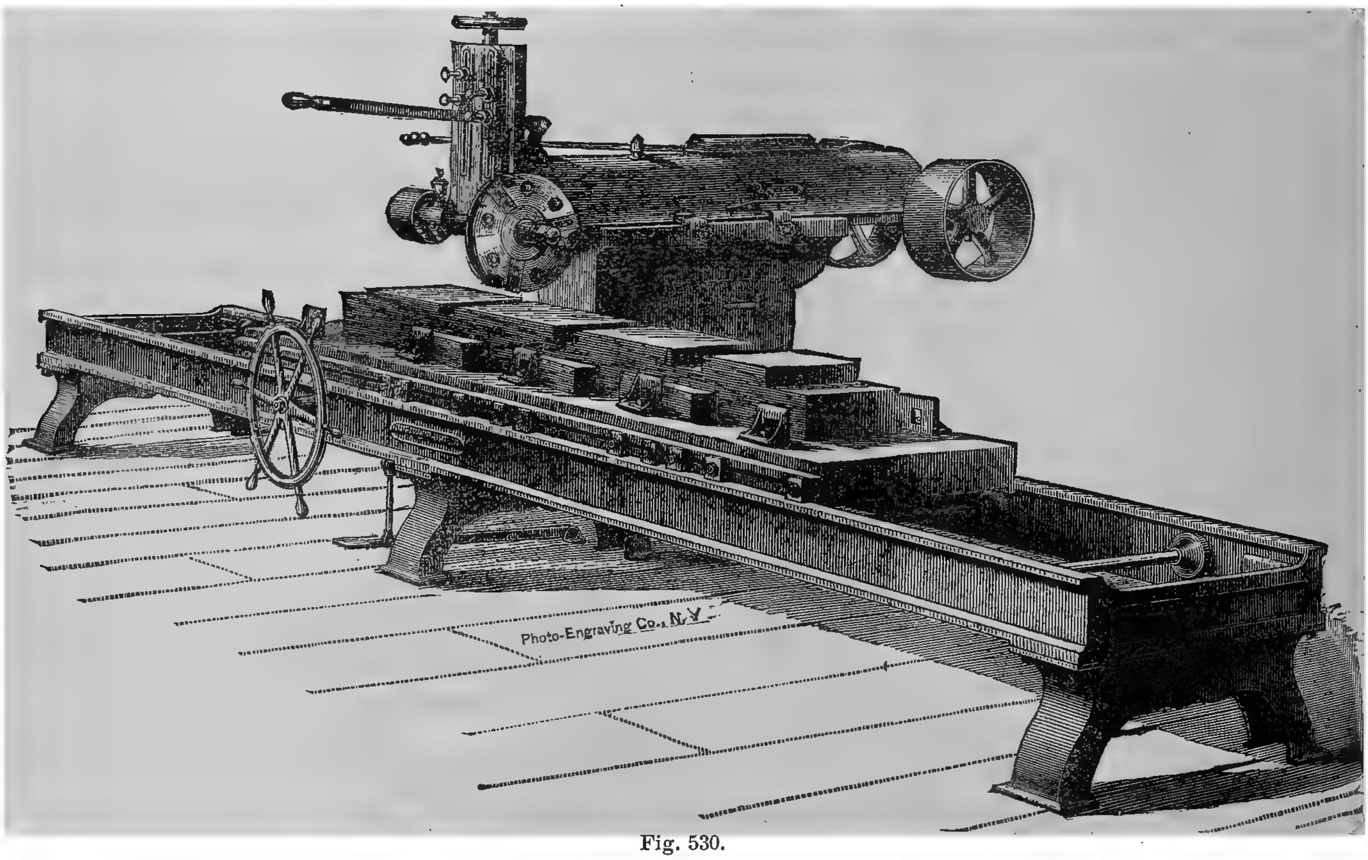

Fig. 530.

from tilting. On the rear of the standard is a third removable head acting like a rotary mortiser to make double tenons, as in the sample at the foot of the machine. This small head is driven by a separate belt outside of the head. The method of adjusting the heads is very obvious, as also the shape of the cutters for a dragging cut. It is more usual, however, where multiple tenons are to be cut to change the system of design, and to have the cutters on an axis at right angles to the axis of the timber. Moreover, as the timber usually is very large and heavy, when multiple tenons are desirable, the cutters are made to traverse across the work which is held stationary.

Figs. 527 *a* and *b* show one form of this type of machine. The work is presented from the front of the machine The cutter-axis is borne on a counter-weighted slide which is moved up and down by the large hand-wheel. The belt passes from the shaft at the base over the cutter-pulley, and thence under and in front of a guide-pulley on the slide. From underneath this it passes over the upper pulley and so back to the driver below. The driving is thereby with constant tension on the belt.

Fig. 528 shows a type of multiple tenoner, by which both ends of a long timber may be tenoned from one face without turning it round. The action is the same as in the preceding designs. The timber is clamped upon the table and finished at one end by lifting the slide, and is then slid over the gap and is tenoned at the other end on the descent of the cutters. End-molding or shaping-cutters may replace the tenoning-heads for certain duties. The clamping devices may be doubled on each side of the gap, with the counter-shaft on the floor at the side. In Fig. 528 the counter-shaft is overhead, and the clamps are single. To prevent splitting and fraying at the lower edge the lip of the gap of the latter is faced with wood, to which the cutters come very close. Gauges are easily

attached for standard lengths upon the tables. Such machines as these will operate on heavy work as fast as it can be presented to them. They possess marked advantages over the machines with similar functions in which the axis of the cutter is vertical and receives a horizontal traverse. This latter arrangement is not in use in this country. It is, of course, a simple operation to make any tenoning-machine cut the shoulders oblique to the long axis of the timber. It is only necessary to make the obvious change in the plane of the table or fence. Any extra-long work can also be done by the use of double sets of cutters.

Closely akin to the tenoners of the previous class are the tools which are called gaining-machines. A gain is a groove cut across the grain of a timber, usually at right angles to its length. The gaining-cutter will, therefore, require spurs or saw-segments at both sides, instead of upon one only. The gain and the tenon may be of the same depth and length in work of given dimensions. But the gain is not at the ends, nor usually near them, and hence a special class of tool is made to produce them. The general type of machine is shown by Figs. 529 and 530. The cutter-axis is driven from the pulley at the rear. Both are borne upon the long gibbed slide, which moves forward across the table and causes the cutters to plow the gain. The shaft at the rear receives its motion from a counter overhead, which stands over the middle point of the traverse of the pulley. The motion backward and forward is effected by a train of gear, which drives a pinion meshing into a rack on the under side of the slide. Adjustable stops make the reciprocation and the arrest of motion when the slide is back to be entirely automatic, but a hand-lever may operate these devices at any time. Power for the traversing is obtained by belt from the counter to the pulley at the side of the base. Both forward and back traverse may be at the same speed, and the cutter may act on both motions as in the vertical tenoner. The cutter-axis is borne on a vertical slide, by which the depth of the gains may be varied. Stops may be fastened to the rear plate, and these may serve to arrest the downward motion of the front slide at any depth or at any series of depths. Gains of different depths may be sunk in the work by using different stops in the four slots of the face. Any of the stops may be made inoperative at will by pulling out a pin in its center. No readjustment is required when the stop is to be used again. The pushing in of the pin of any one stop causes it to serve. The weight of the slide is borne either by a counter-weight on the hand-lever, or by a series of springs in the back-plate. The stuff to be gained rests on a carriage, to which it is secured by wedging it against knee-blocks. The table moves on friction-rollers, and is guided by ways. It is moved by rack and pinion from the large hand-wheel in front. In front of the carriage or table is a T-slot, by which a series of dogs or chocks may be secured. In the path of their motion is a projecting pin, which may be pulled out of the way by treadle or handle, but which returns to its place by a spring. These stops may be spaced so as to produce standard spaces or widths of gain in series of duplicates, without loss of time for measurement. Their function is identical with that of the stops on the vertical slide, and add immensely to the capacity of the machines.

In the design of Figs. 531 *a* and *b*, the long slide has a quick-return. The vertical lever which projects up through a slot in the slide is pivoted upon the center just under the ways. The arm which hangs downward from

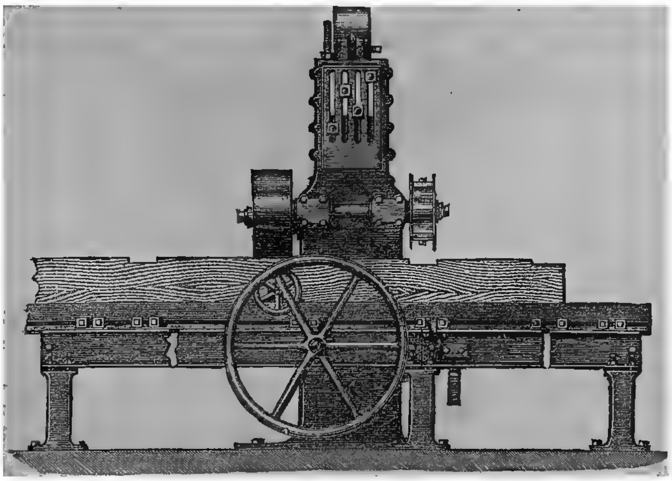

Fig. 531 *a*.

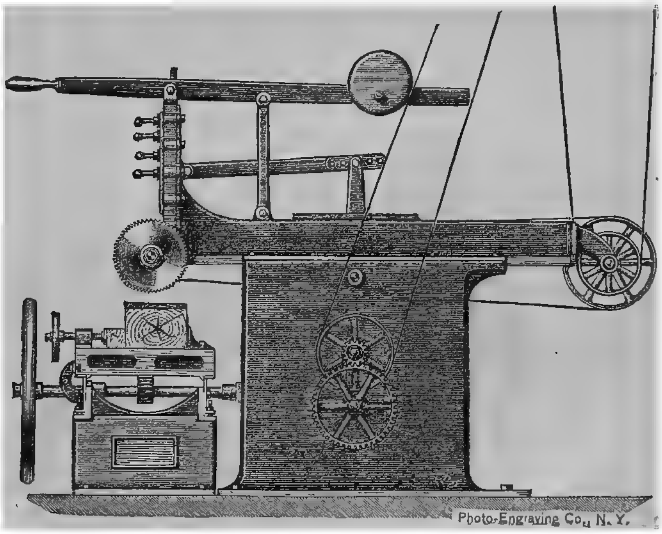

Fig. 531 *b*.

this center carries a slot into which is fitted a crank upon the axis of the larger lower gear. It will be seen that when the crank is down it acts to move the slide forward slowly with long leverage. When the crank is up it acts nearer to the center of motion, and brings the slide back rapidly. The horizontal link has several holes to enable the slide to overhang more or less. In this design a full saw is used on each side of the paring-cutters. Segments of saw-plate are more usual.

Fig. 532 shows the ordinary form of groover-head as used for sash- and door-work. The cutters have spurs, and are held in place by taper compression-bolts.

Fig. 533 shows a type of expanding-head for gaining-machines. The cutters are compressed by bolts in slots,

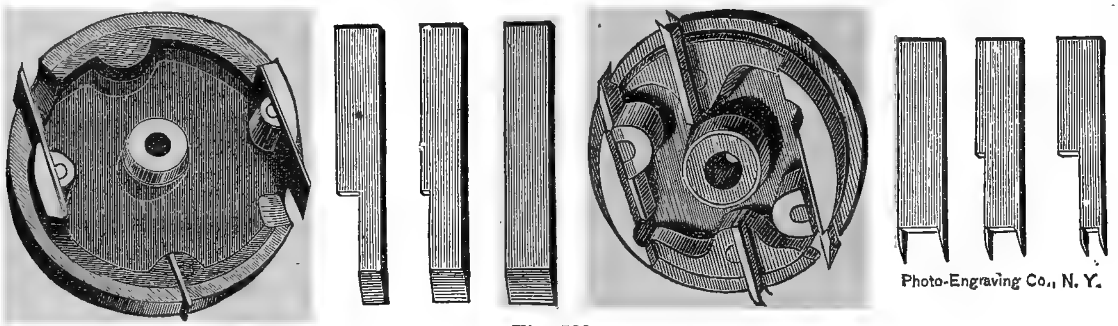

Fig. 532.

and, by changing the chisels, the widths of the gains may be varied. Different types of expanding-heads are used for various purposes, such as dado work, for example, differing with the method of mounting (Figs. 534 and 535).

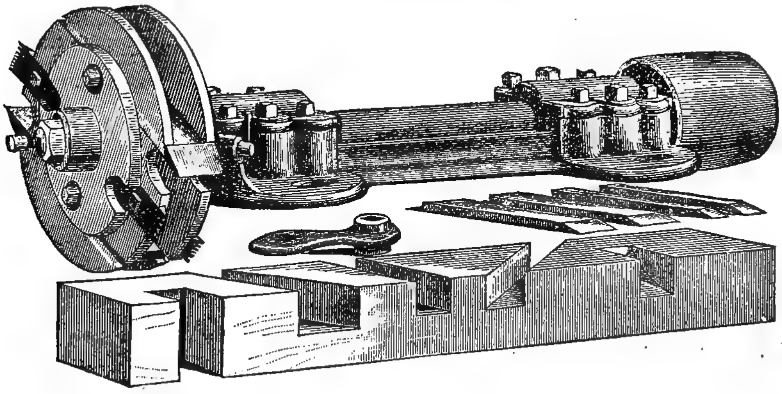

Fig. 533.

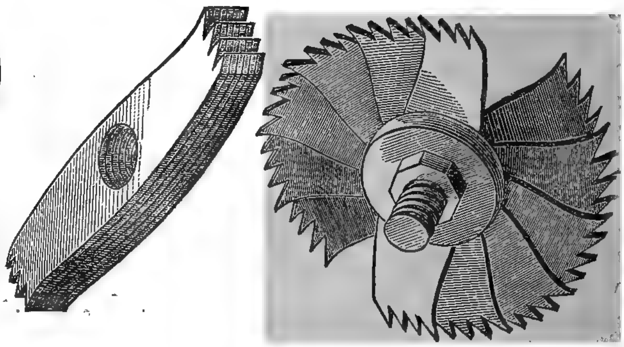

Fig. 534.

A reference to tenoning-machines would be incomplete if it did not embrace the machines for special tenoning, such as are required in blinds and wheel-spokes. The slat of the blind, having been shaped upon a sticker, is held in a chuck, and revolved while it is presented to the cutter. The tenon is made round by the rotation, and the end does not split or fray.

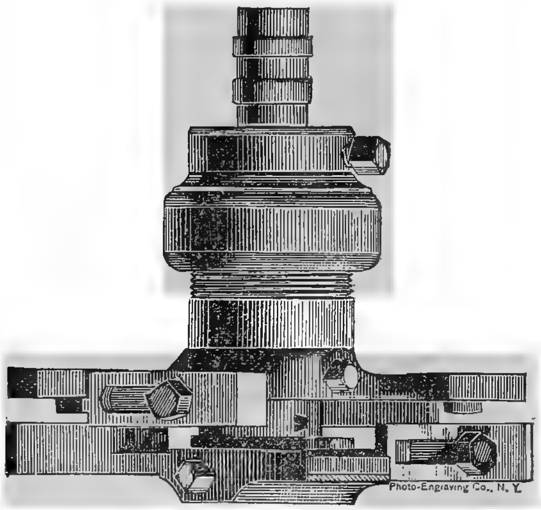

Fig. 535.

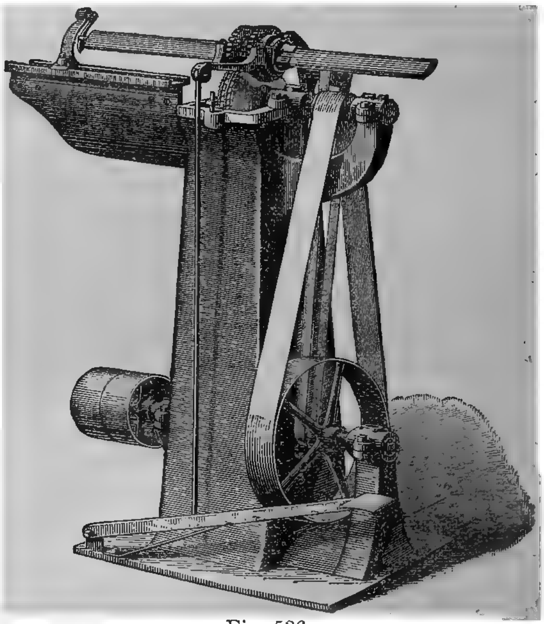

Fig. 536.

Fig. 536 shows a form of machine embodying the features of the Ellis & Bickford patents, which divides the slat and cuts two tenons in the middle. In the Ellis machine the tenons are cut at each end of the slat by two cutters.

Fig. 537 illustrates an oval tenoning-machine as applied to wheel-work. The wheel is chucked on its hub, and a small circular saw cuts all spokes to the same length. The spoke which is operated on is held by geared centering-clamps, which bring the center of a spoke of any size to the center of the revolving disks. The upper part of the machine which carries the cutter-heads has two disks, which are revolved by a series of cut gearing, governed by a lever for the foot, which acts upon friction-pulleys and is under the control of the operator. The

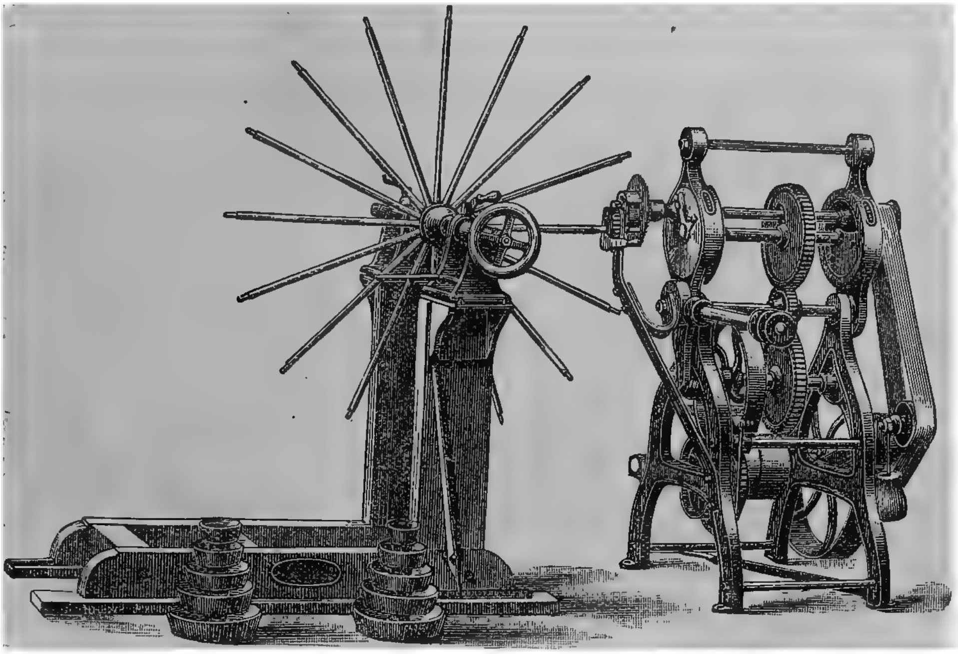

Fig. 537.

arbor on which the cutter-head and saw are secured passes through the revolving disks near their peripheries, the boxes in which it runs being secured to the disks, but they are adjustable by means of cams for the different tenons. The upper part of the machine in which the disks revolve has a vibrating motion given to it by the weighted hand-lever. By depressing this lever the cutter-head is brought forward and cuts the oval, which may be varied in size to suit the work required. The oval tenon reduces the danger of splitting the felloes, and may render wedging unnecessary. Wheel-making may also use machines for truing spoke-tenons, for bevel-facing, shaping and throating the hub-ends of spokes, or for making the simple round tenons used on ordinary spokes. Most of these, however, become special machines, applicable for one industry only.

§ 53.

MORTISING-MACHINES—ROUTING-MACHINES.

The mortise receives the projecting tenon. The cutter must produce a cavity in the solid part of the timber, and must act first to cut the fibers, and then to pare away the chips. Mortising-machines are of two general classes. The first includes those which act by rotating cutters, which cut both upon sides and end. The second class includes those which act by a reciprocating chisel. This latter class has several varieties. The principle of the rotary mortisers is found in the panel-sinkers and bracket-molding or carving-machines.

In a machine for small work, such as the chair and blind industries, the rotating arbor is pivoted at the rear, and receives a vibratory motion from a slower moving wrist-plate. This motion may be graduated at will and determines the length of the mortise. The slight curvature at the bottom of the slot is no objection.

Figs. 538 and 539 show two designs for the largest class of work, the older design having a wood frame, while the more recent pattern is of iron. The cutter has horizontal and vertical traverse by levers controlled by stops, and the length of the mortises is governed by stops on the feeding-table, as in the gaining-machines. The cutter-slide is counter-weighted to relieve the strain in widening mortises, and power-feed may be engaged to save time in setting the work. The new machine has capacity for mortises 12 inches deep and 16 inches wide and of any length desired. The high speed and freedom from jar adapt these rotary machines for the heaviest work in hardest or most unfavorable lumber. There seems good reason for the preference felt for them by many engineers.

The reciprocating mortisers belong to four classes. In the first class the chisel is driven from a simple wrist-plate by connecting-links, and the work is fed up to the chisel by the foot of the operator, which depresses a treadle. This type is adapted for cabinet and other work upon light material which is easily lifted. Types

of these machines are shown by Figs. 540, 541, 542, and 543. Figs. 540 and 542 show a boring attachment, which is very usual when hard woods are to be handled. In softer woods the chisel may penetrate without previous boring of the holes. The stroke of the chisel being unvarying, the depth and severity of its blow are gauged

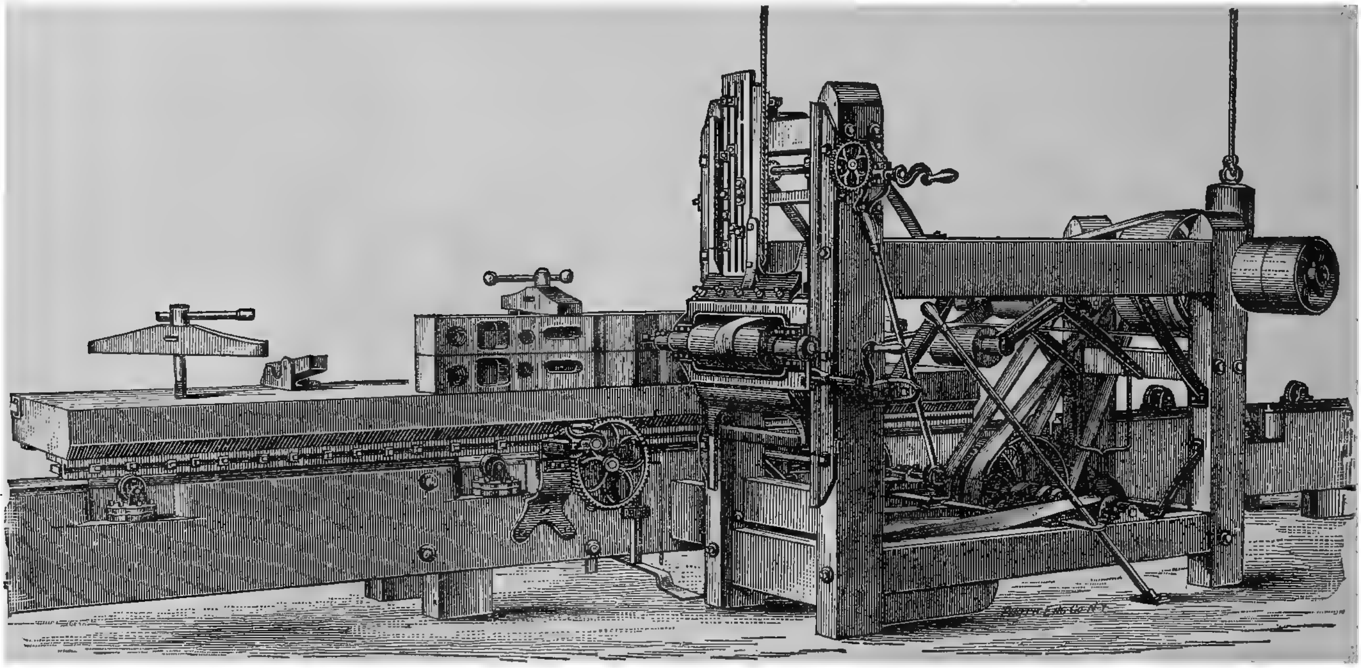

Fig. 538.

by the height of the treadle, and this may be made progressive. The work may be clamped to the table and fed along sidewise by rack and pinion, or it may be held in the hands only. The tables are made adjustable for various thicknesses by screws geared to crank-arbors, or by compounding the table vertically. The depth of the mortise is gauged by the fall of the treadle. In Figs. 541 and 542 the treadle is compound. In the former case the

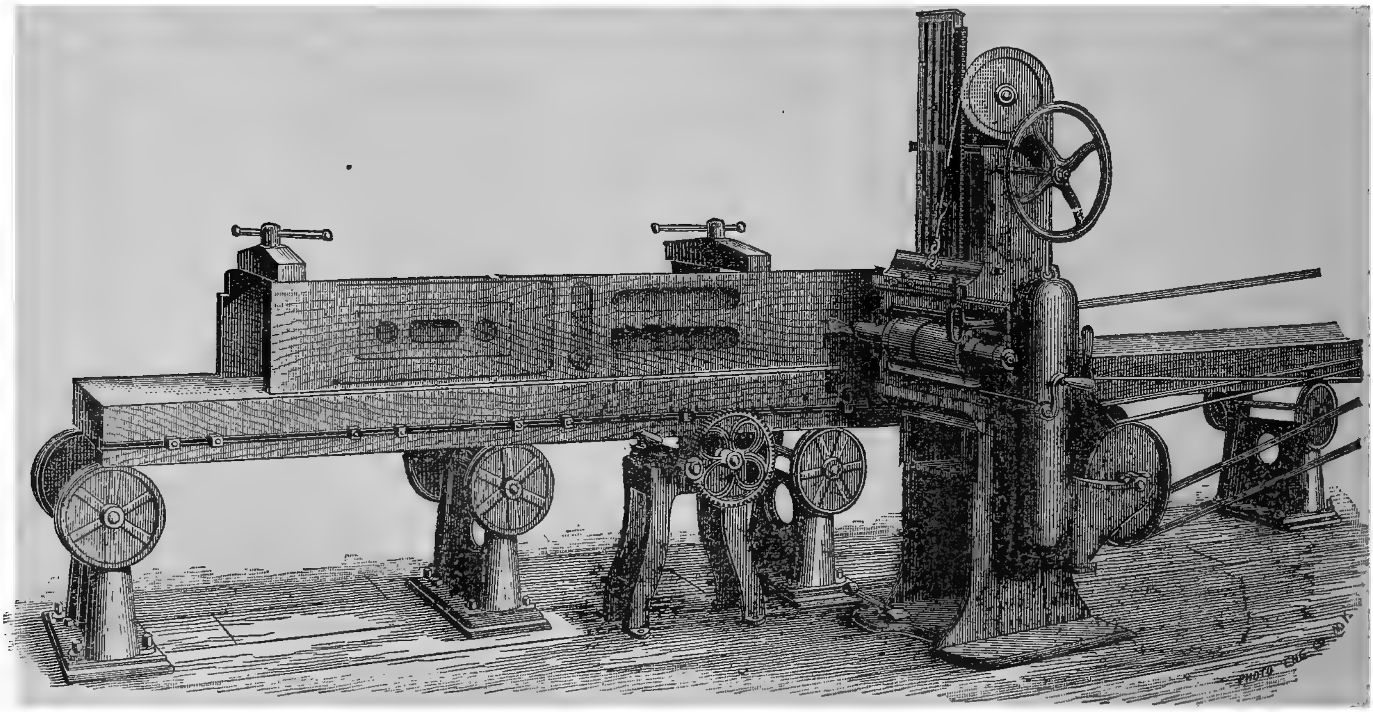

Fig. 539.

adjustment is by the set-screw. In the latter case it is by pawl and segment of a ratchet-wheel. In the designs of this class the treadle and the foot of the operator must receive and resist all the blows. In Figs. 540 and 543 the treadle resistance is so distributed by the truss construction that a large component of the deepest blows passes into the axis of the treadle and relieves the foot-pad. Ease to the operator is also secured by increasing

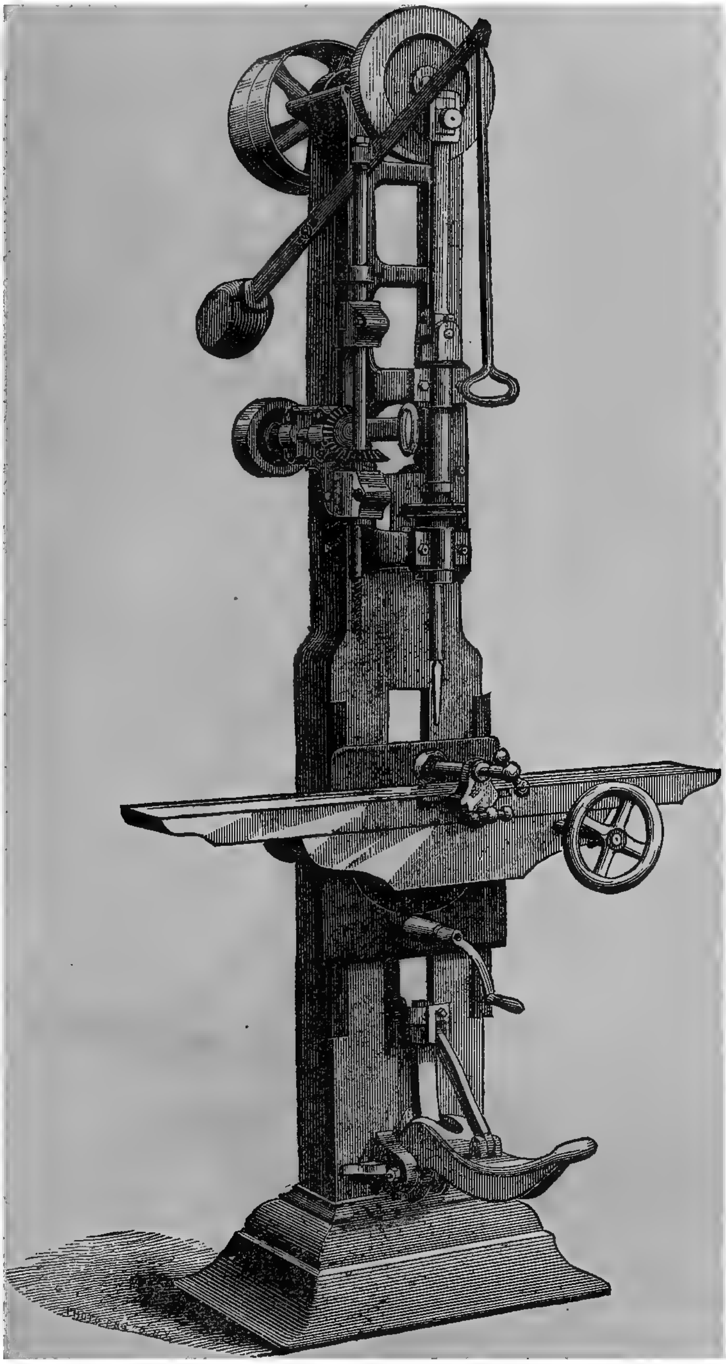

Fig. 540.

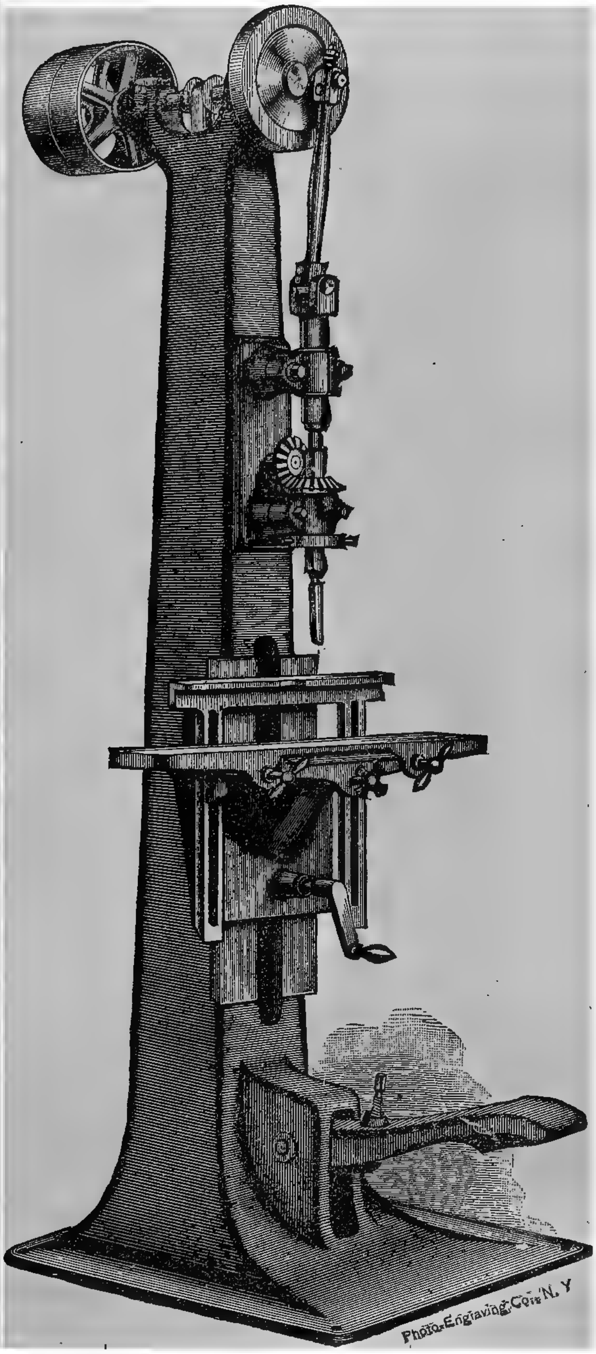

Fig. 541.

the inertia of the table and by running the chisel at very high speeds, which is possible when the reciprocating parts are light. The usual speeds are 500 blows per minute. The double wrist-plate design of Fig. 543 permits 800 blows per minute. It is necessary to reverse the chisel at intervals to secure the proper action of the spurs and straight ends to the mortise. This is done by several different devices. Figs. 540 and 543 use the round belt

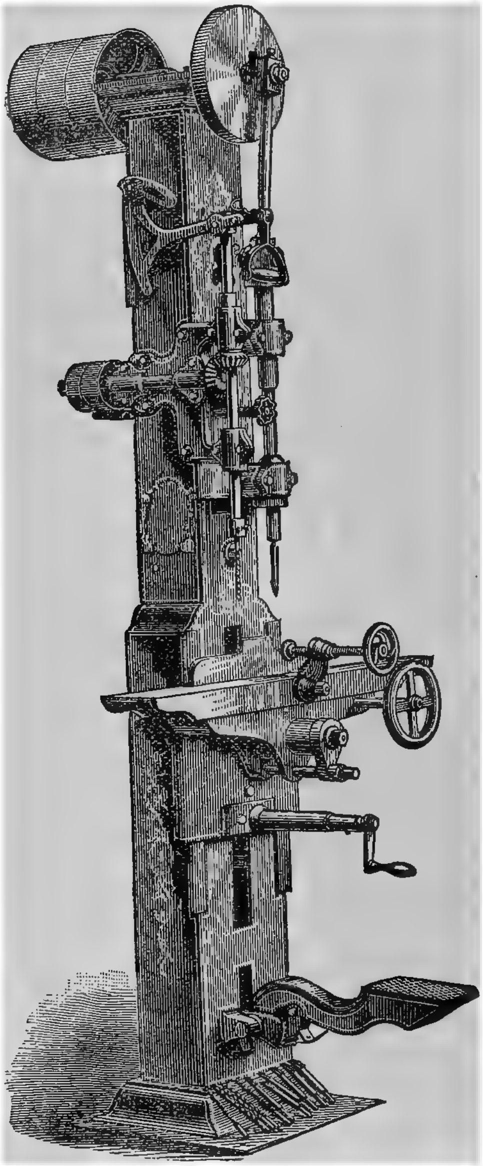

Fig. 542.

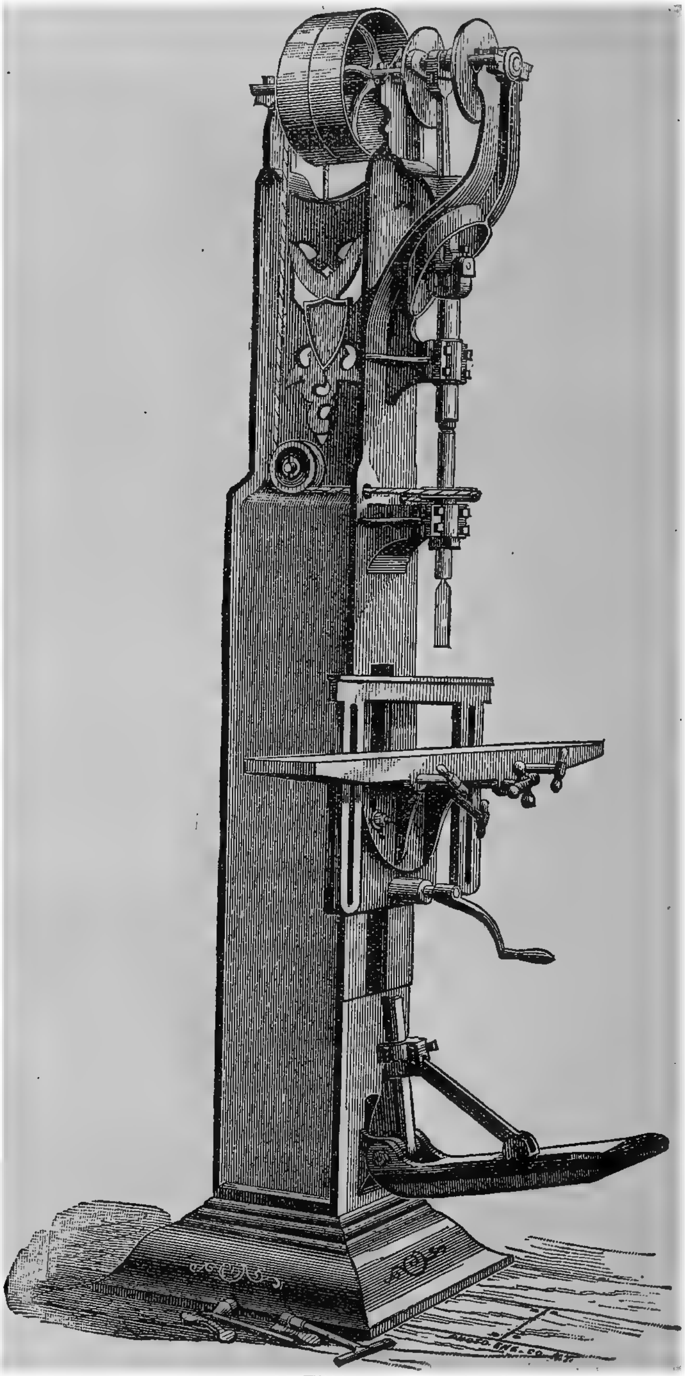

Fig. 543.

device, which slips around the pulley, except when the release of stops permit the bar to turn. In Fig. 541 flat belt is used and the pair of bevel-gear. In the tools of the builder of Fig. 542 there is a bevel-gear on the splined chisel-bar which is in gear with corresponding sector of a bevel-wheel. As the treadle rises it lifts a wedge-point, which strikes a corresponding wedge-point connected to the sector, and reverses the chisel, even if the machine is not running. This latter feature is often a convenience. The reversal of the chisel-bar necessitates an extra joint in the mechanism, which is to be avoided when possible. The rolling fulcrum for the boring-bar of Fig. 542 is a neat feature and avoids a slotted joint or an extra link.

Fig. 544 illustrates a unique machine with two reciprocating chisels. The machine shown is specially fitted for hub-work, and will stagger the mortises as well as do them straight. The table is lifted automatically by a cam-bearing on a roller. The cranks are connected by a drag-link, and the wrist-plate has a brake. The feed for raising the treadle is intermittent and easily disengaged.

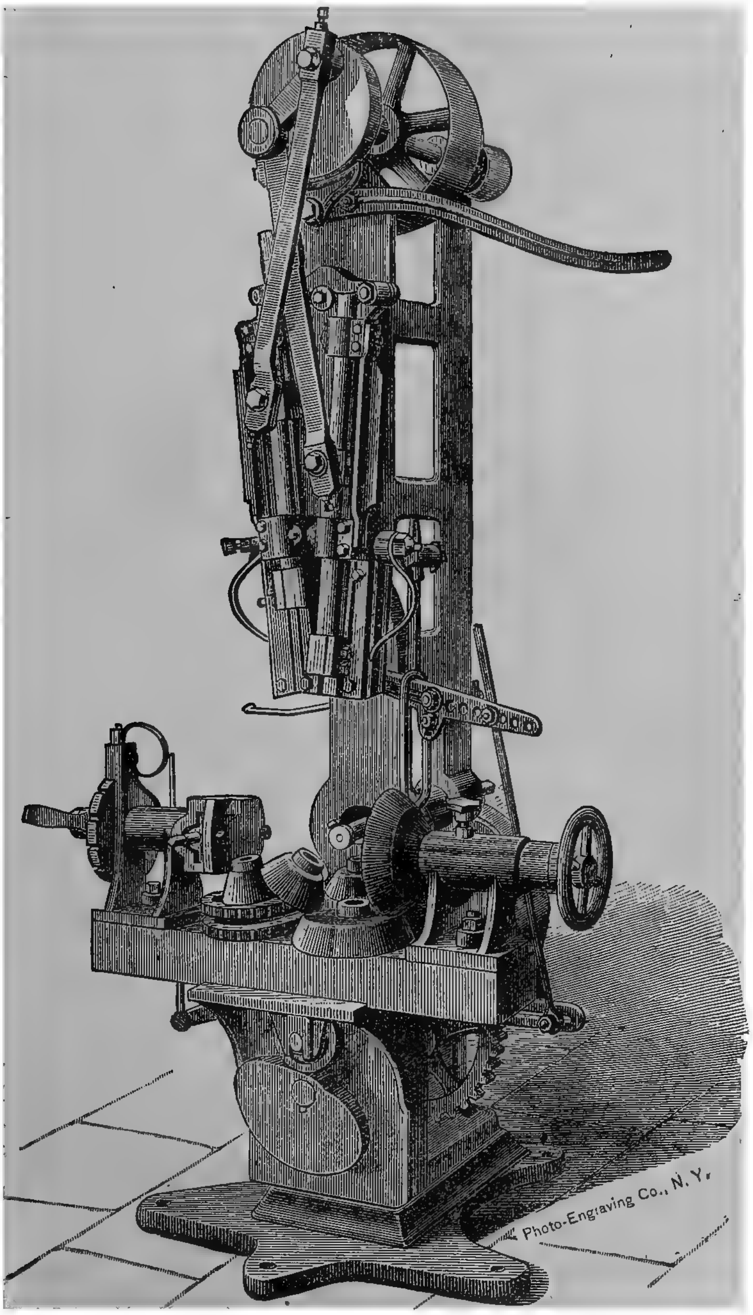

Fig. 544.

The second great class of mortisers includes those in which the table is fixed and the crank-shaft rises and falls to vary the depth of the blow and the mortise. Fig. 545 illustrates a machine of this class, with boring attachments. It has the advantage that it is the rotating parts which receive the shocks of impact before they reach the treadle, and these may be heavy. The counter-weight of the crank and attachments also helps the treadle, but these machines must run at high speeds, and cannot withstand the slower speeds in the form shown. In the heavy hub mortiser by the same builders (Fig. 546) the connection from the crank-shaft below to the abutment above is by an elbow-joint. As this is straightened out by the treadle the chisel-point, with constant throw, comes lower and lower. The elbow is straightened by flexible connection passing over an eccentric disk, so that the leverage of the

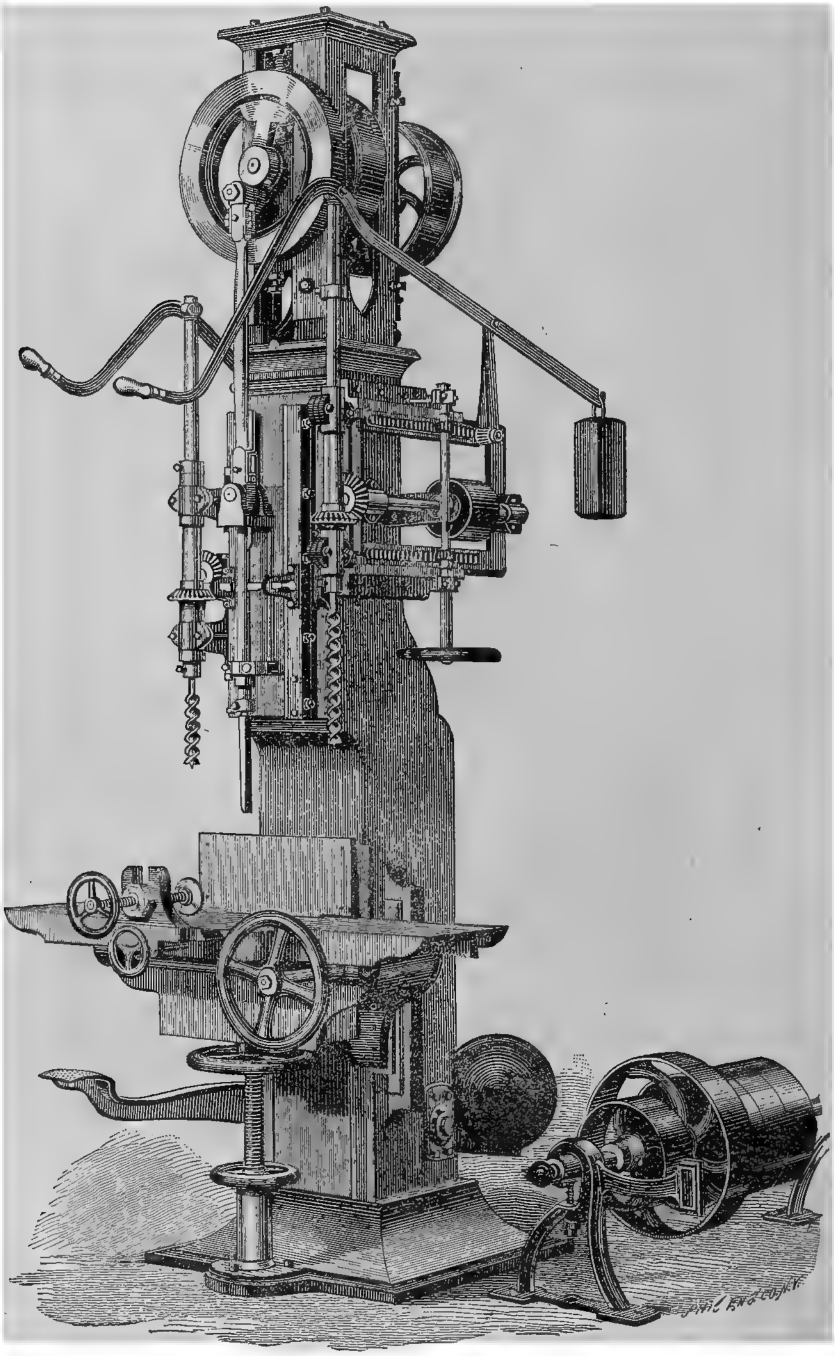

Fig. 545.

treadle is greater as the blows are heavier. The crank-shaft frame is counter-weighted. This is a manifest improvement on the earlier designs, in which the crank-shaft floated directly from the treadle. The third class of chisel-mortisers includes those in which the motion of the bar is made variable by varying the length of the lever-arm which drives it. This may be done by varying the crank-arm, or, as in Fig. 547, by making the crank swing a pivoted lever, upon which slides the wrist-block which drives the chisel. The position of the block is controlled by the links from the treadle, and the stroke may vary from nearly the full stroke of the crank to almost zero.

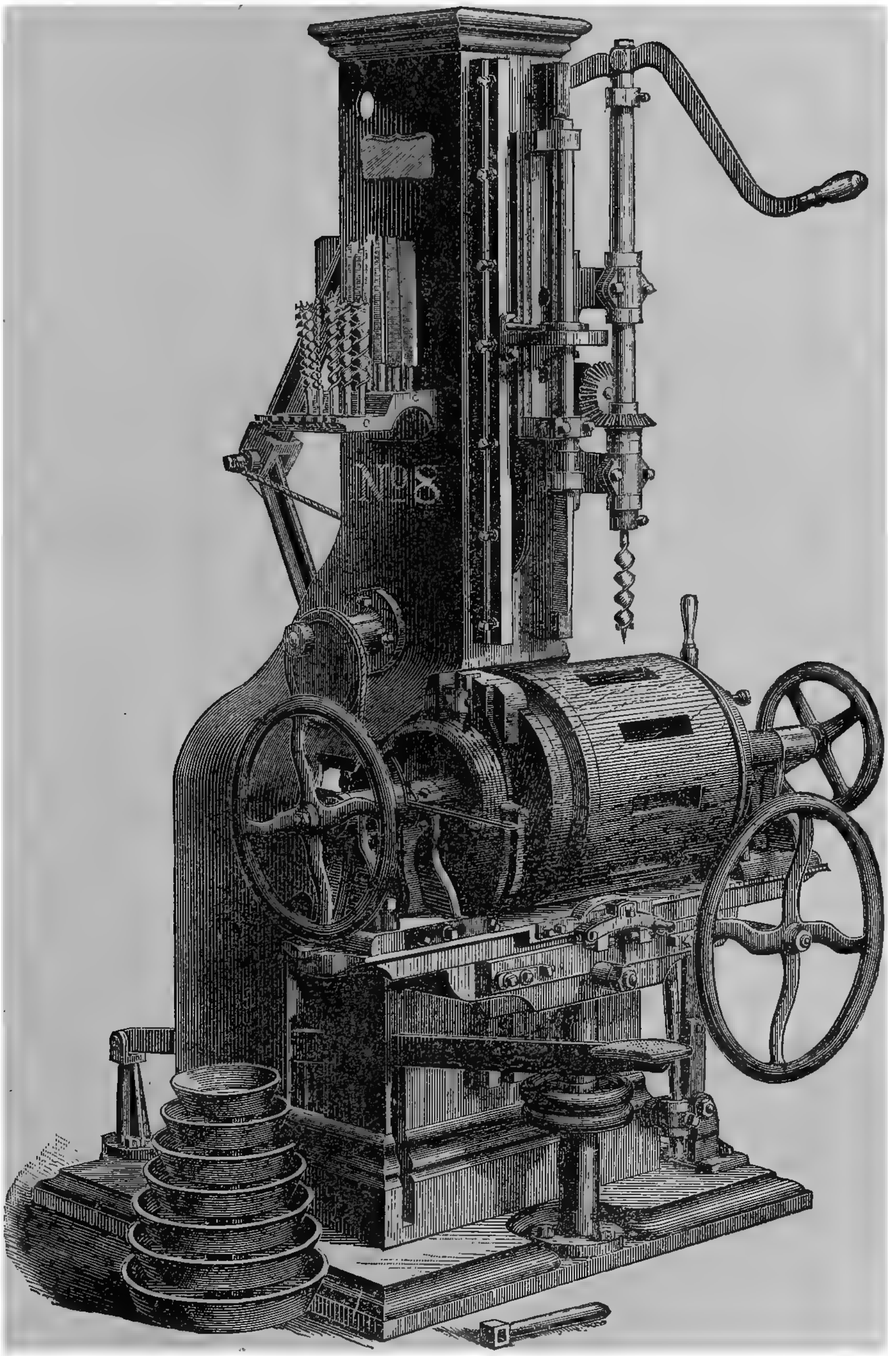

Fig. 546.

But this variation takes place on both sides of the central position of the chisel, and the stroke must be twice as long as the depth of the mortise when measured from the position of rest. This limits the speed of the tool, and multiplies the number of joints between the bar and the crank-pin. The fourth class includes the designs of the type shown by Fig. 548. In this form the stroke may be graduated from zero to the full throw of the crank, but the still point is when the chisel is at the top of its stroke. The variation is caused by varying the length of the line between the crank and the head of the chisel-bar. The connecting-rod is jointed in the middle, and a third

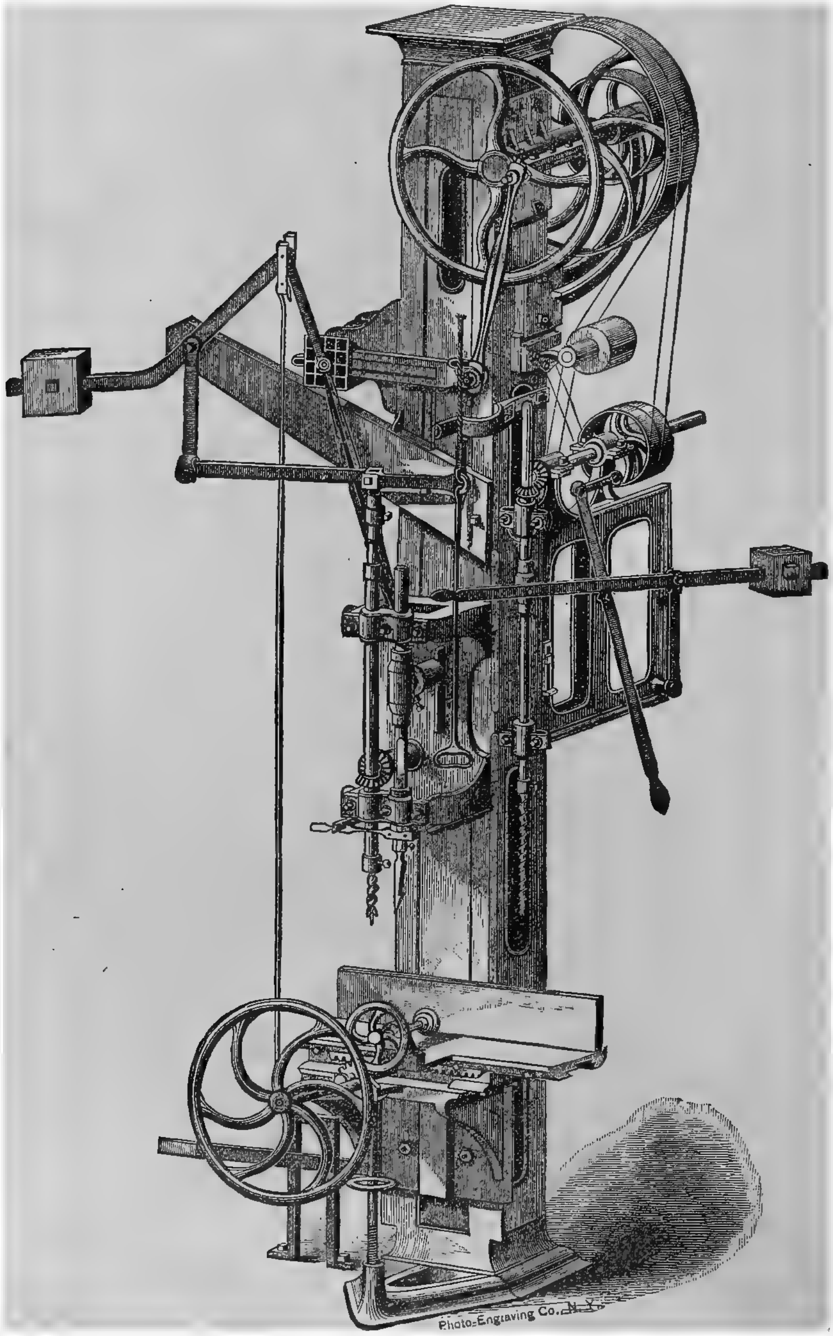

Fig. 547.

link may throw the former into an elbow or straighten it out. When the rod is bent, the thrust of the first link is entirely oblique to the travel of the bar, and it causes no motion in the latter. When the links are straightened, the whole thrust goes into the bar. At intermediate points a component is absorbed in the third link, and the rest causes graduated motion in the bar. The third link is controlled by the foot-treadle from the end of the crank shown, which is counter-weighted. The boring attachment on the left slides outward by rack from the hand-wheel for general boring. The other at the right is in the line of the chisel for mortising.

The fifth class of chisel mortisers includes those which have a progressive downward motion of the chisel-bar to the required depth from a still point, but are without flexed joints in the links. Such a one is shown by Fig. 549. The chisel-bar is worked from the front end of a vibrating beam, pivoted at the middle. At the rear end of this

beam is an oscillating box, to which fits a lever which is worked by a connecting-rod from the wrist-pin on the balance-wheel. This second lever is adjusted for position in the oscillating box by a rack and pinion. When the box is near the center of motion the chisel-bar is up, and it has no stroke. As the lever is drawn forward the stroke increases in length but diminishes in power. The boring-mandrel has a special belt-motion, by which it can be driven either in line of the chisel or at any point across the work. In another somewhat similar design, instead of

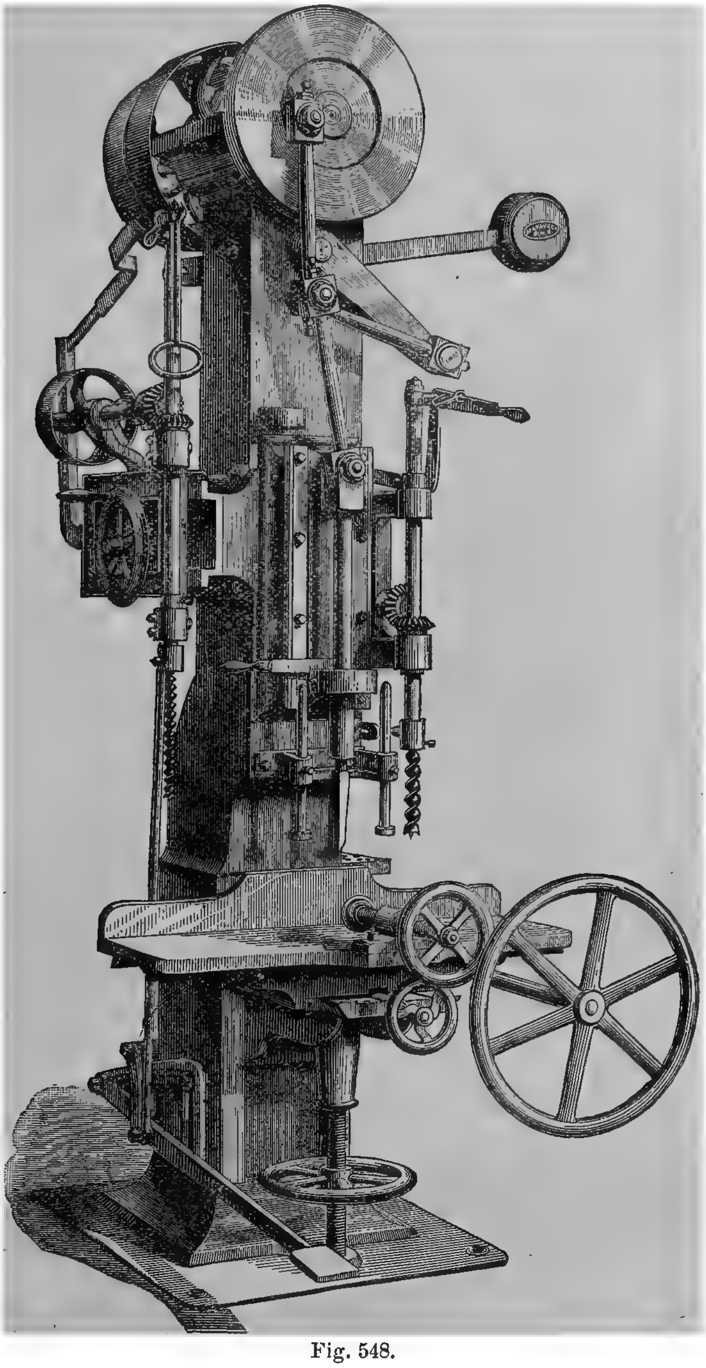

Fig. 548.

shifting the second lever, the connecting-rod is jointed as in the fourth class, and the third link is moved from an arm which carries a quadrant with worm-teeth driven by a worm. As the worm is turned in one direction the links pass into an elbow-joint, and the motion of the chisel grows less and less. The worm-shaft is turned by a belt from a shaft driven by a three-cone combination, the friction being by paper on iron. The jar of the links is received by the worm, which is held from slipping on its shaft lengthwise by a stiff steel spring. This receives the shocks and none reach the foot-treadle. A counter-weight puts into action the cone, which lifts the chisel, and the downward feed is given when the weight is overcome by the foot of the operator on a treadle. The flexed elbow-joint takes up the bar to a point $1\frac{1}{2}$ inches higher than the top of the stroke when the links are straight. The reversal of the bar is effected by a round belt upon a grooved wheel. This belt is prevented from acting during the stroke by four stops upon the face of a horizontal wheel. These stops are alternately in different planes, and the motion of the

treadle releases one stop but catches the second. This causes a revolution through 90°. The release of the treadle releases the second stop and catches the third, whereby the bar passes through 90° more, or through a half revolution in all. The reversal is thereby always effected in air, when the chisel is up, and may be entirely automatic.

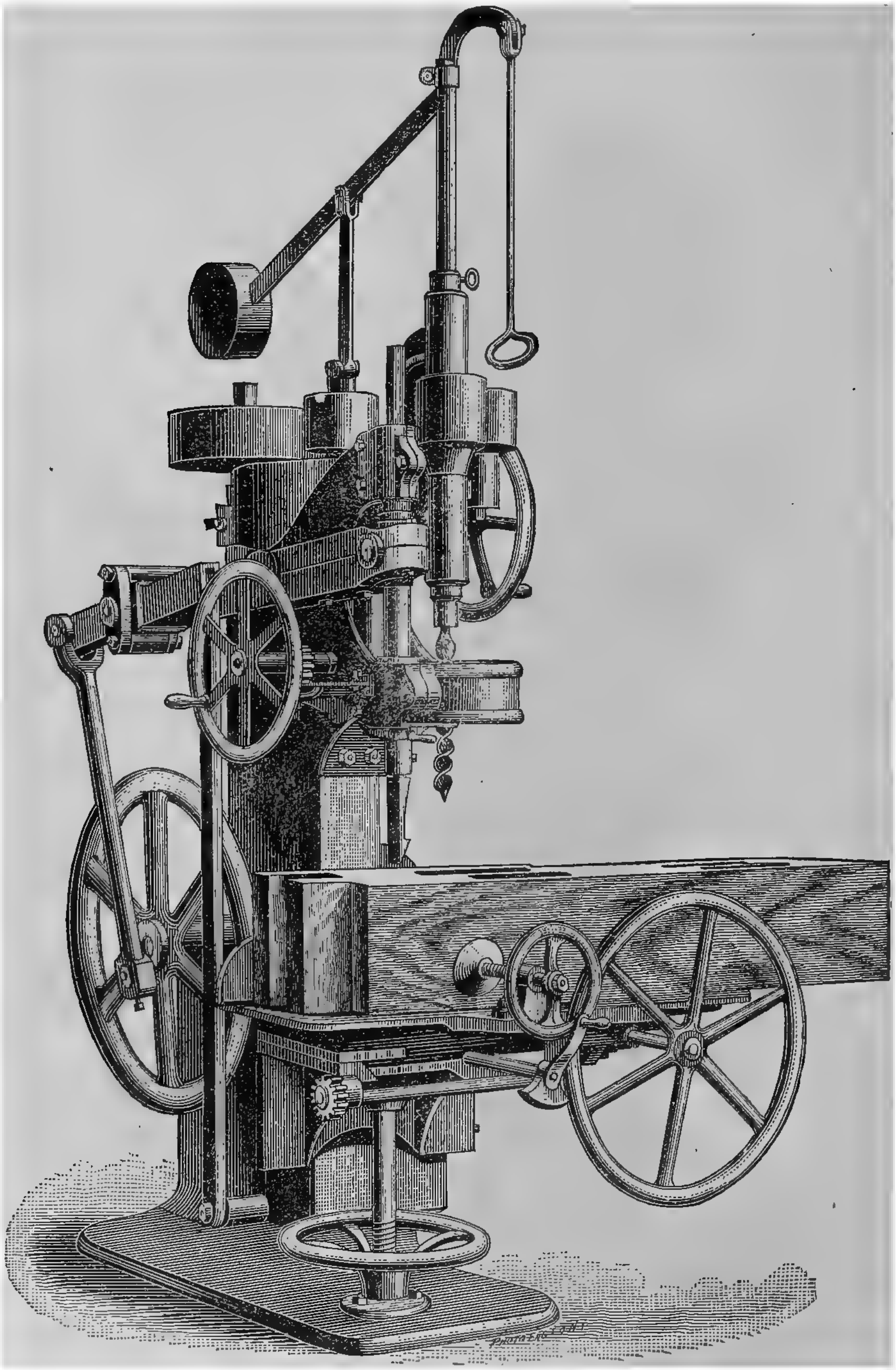

Fig. 549.

The mortising-machines belonging to the various classes illustrated give a wide range of adaptation. With one type or another every class of work can be satisfactorily done, and the details of their construction are of a high grade of mechanical excellence.

§ 54.

BORING-MACHINES.

ese machines belong unmistakably to the class of tools acting both by paring and severing the fibers. The spur acts to sever material which is split off by the edge.

In the several mortising-machines are seen types which illustrate post-boring machines. A vertical shaft, splined, is driven by a pair of bevel-gear. A hand-lever attached to a collar at the upper end draws down the mandrel which practically feeds itself, and a counter-weight retracts the tool when the hole is made. For the larger post-borers, such as Fig. 550, a second motion horizontally is given by compounding the bracket, so that

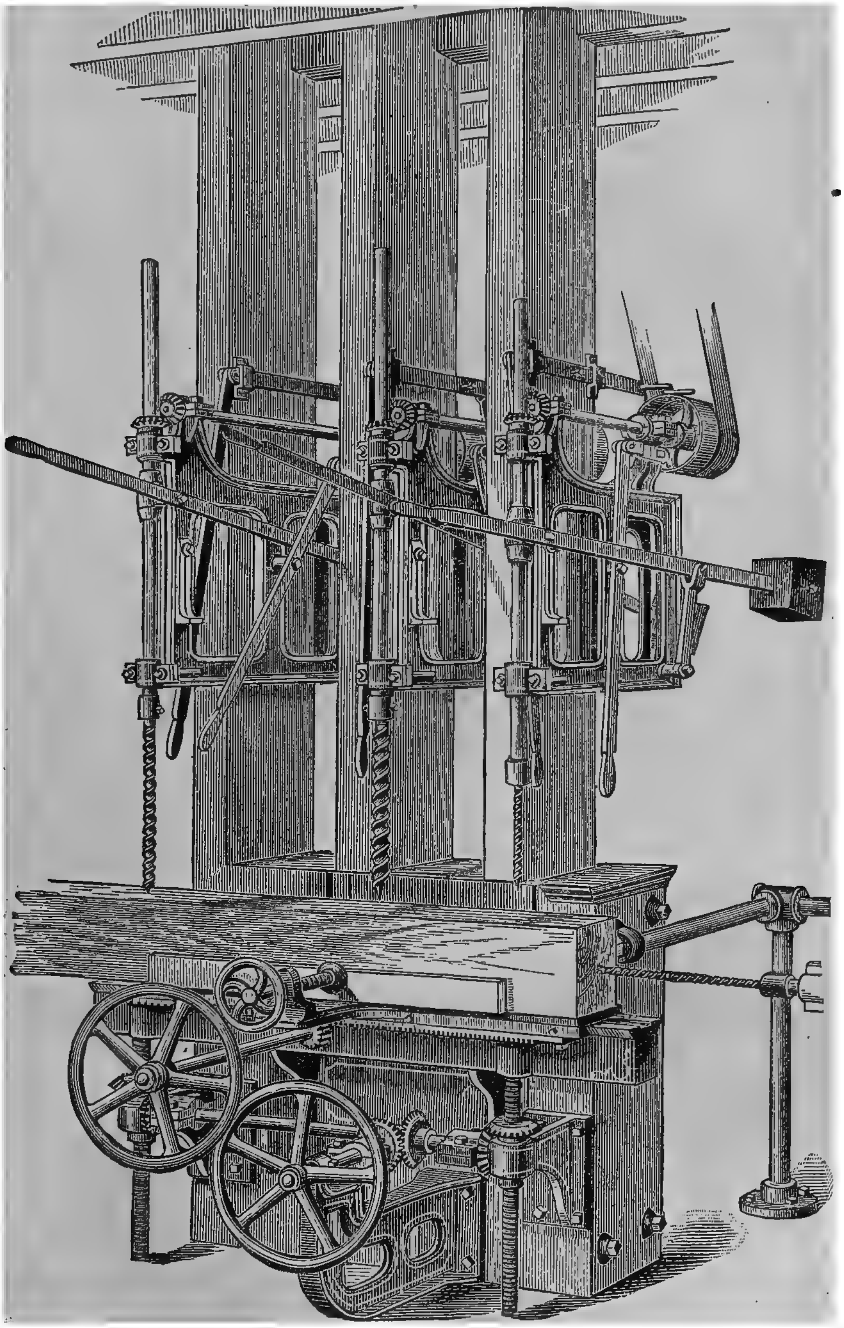

Fig. 550.

work of greater width can be bored. In the design shown, which is for car- and bridge-work, the heavy table and work is raised by geared screws, and its horizontal adjustment is made by rack and pinion. The posts may be spaced for standard intervals, or at random. The brackets are pulled forward by levers, the belt-shaft being splined. For horizontal boring in the ends of long timbers, the device of Fig. 551 is used. A similar bracket-

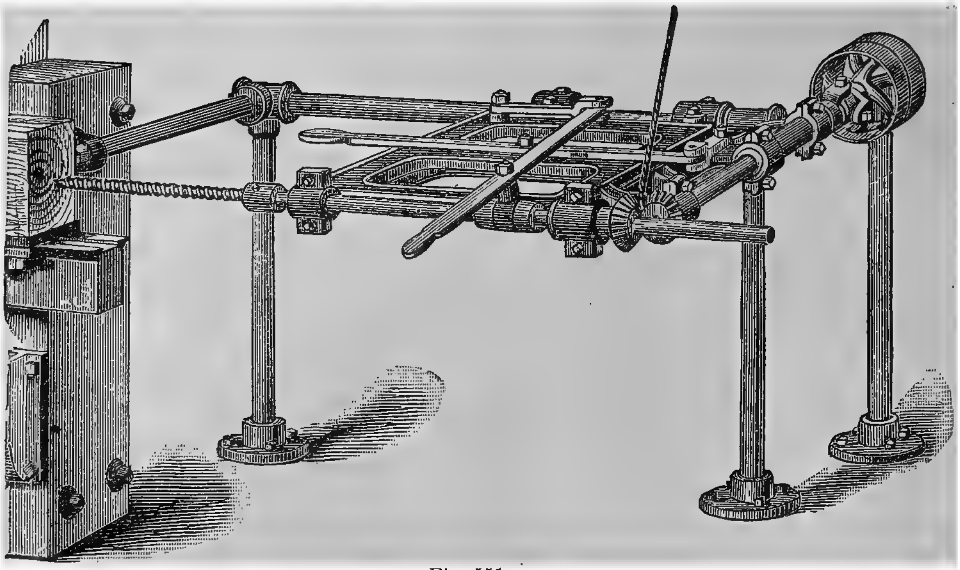

Fig. 551.

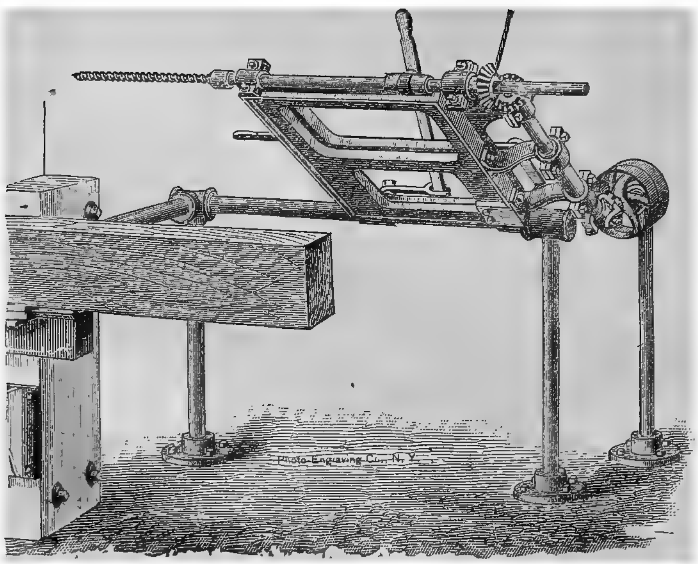

Fig. 552.

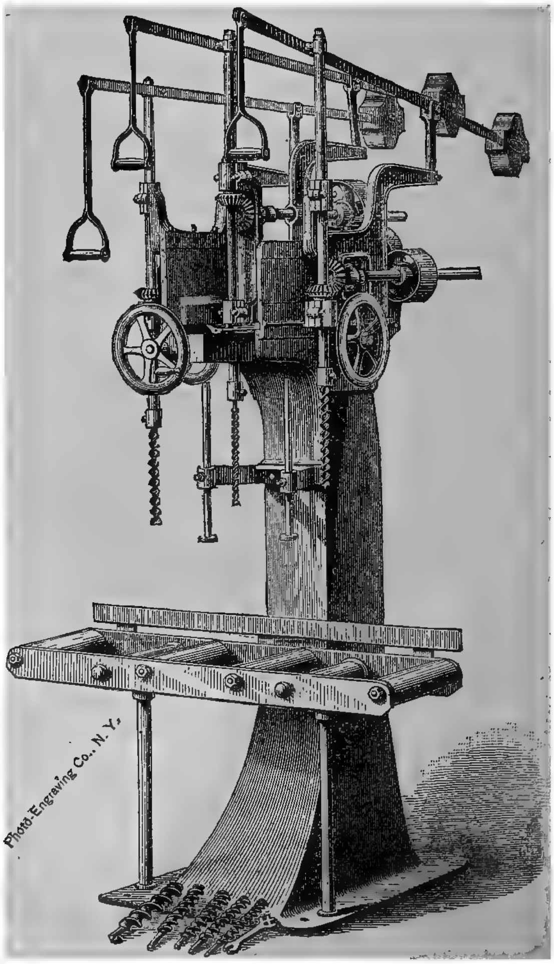

Fig. 553.

frame is pivoted at the rear and counter-weighted. The pulley-mandrel has a universal joint in it so that the whole apparatus may be lifted so as to let the timber pass it (Fig. 552). A standard iron vertical boring-machine for several bits is illustrated by Fig. 553. The two outer frames are fed forward by rack and pinion from the hand-wheels, and the central one by a screw. They are all driven by one belt, the pulley on the central shaft being larger than the other two. That causes it to turn more slowly, and fits it for the largest auger of the set. The table has friction-rolls for the easy handling of the heavy work for which the tool is adapted. A type of vertical borer, designed to be secured to a post, is shown by Fig. 554. The mandrel is driven by a quarter-twist-belt, and has no horizontal traverse. The pressure for feed may be by hand or by foot. For horizontal boring in car and large work the rotary mortisers may be applied, or tools with the same capabilities.

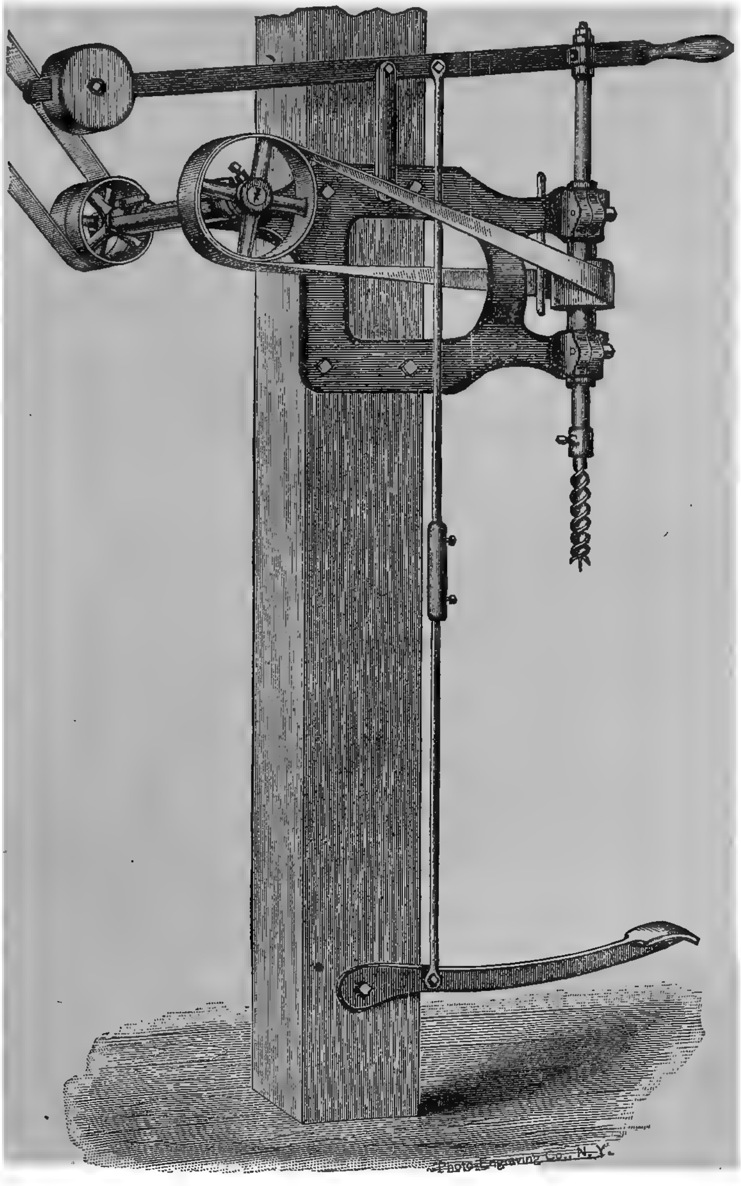

Fig. 554.

Figs. 555 and 556 show their general construction. A counter-weighted slide carries the boring-arbor, and gives vertical adjustment by screws and hand-crank. Power is furnished directly by belt over guide-pulleys or from the counter in the mean horizontal plane. Fig. 555 shows the use of a stop for gauging the depth of holes. The feed is by the handles shown. A machine for angular or radial boring is illustrated by Fig. 557. The belt is tightened by a pulley with a weight hung in a slack bight overhead, by which any elevation or angle may be secured for the mandrel. This machine meets a need in car- and bridge-work, where truss-rods are to pass obliquely through the ends of the timbers. It will also bore with the grain on the ends of work. For the smaller work of miscellaneous shops, what are known as universal machines are approved. As in the larger types, these are vertical and horizontal.

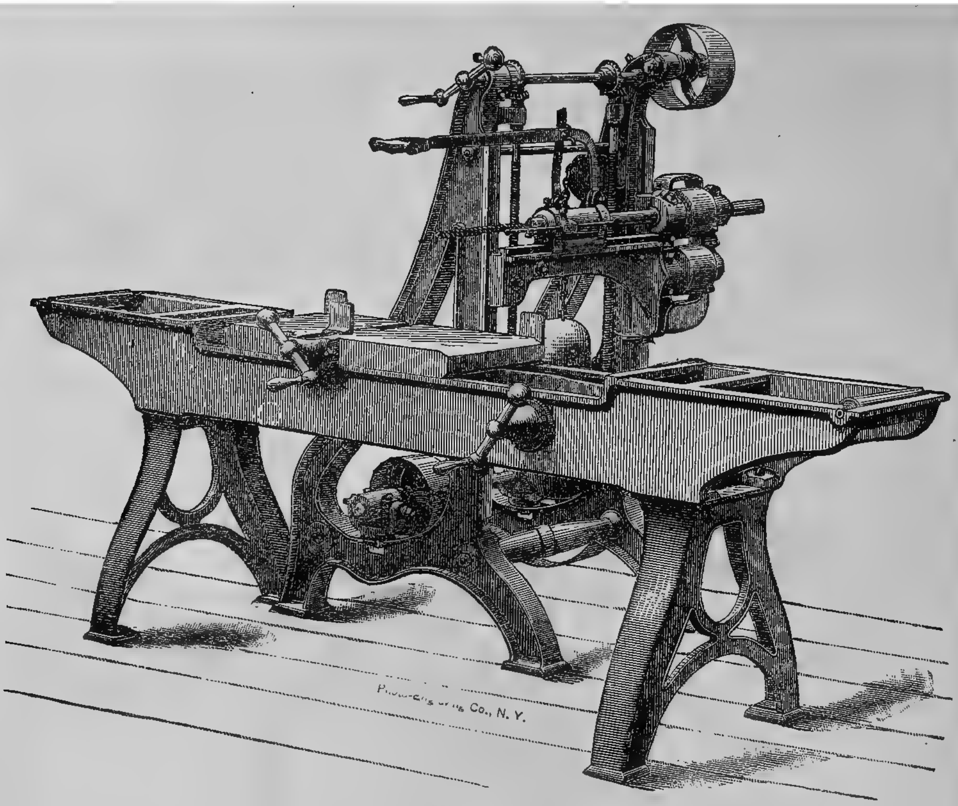

Fig. 555.

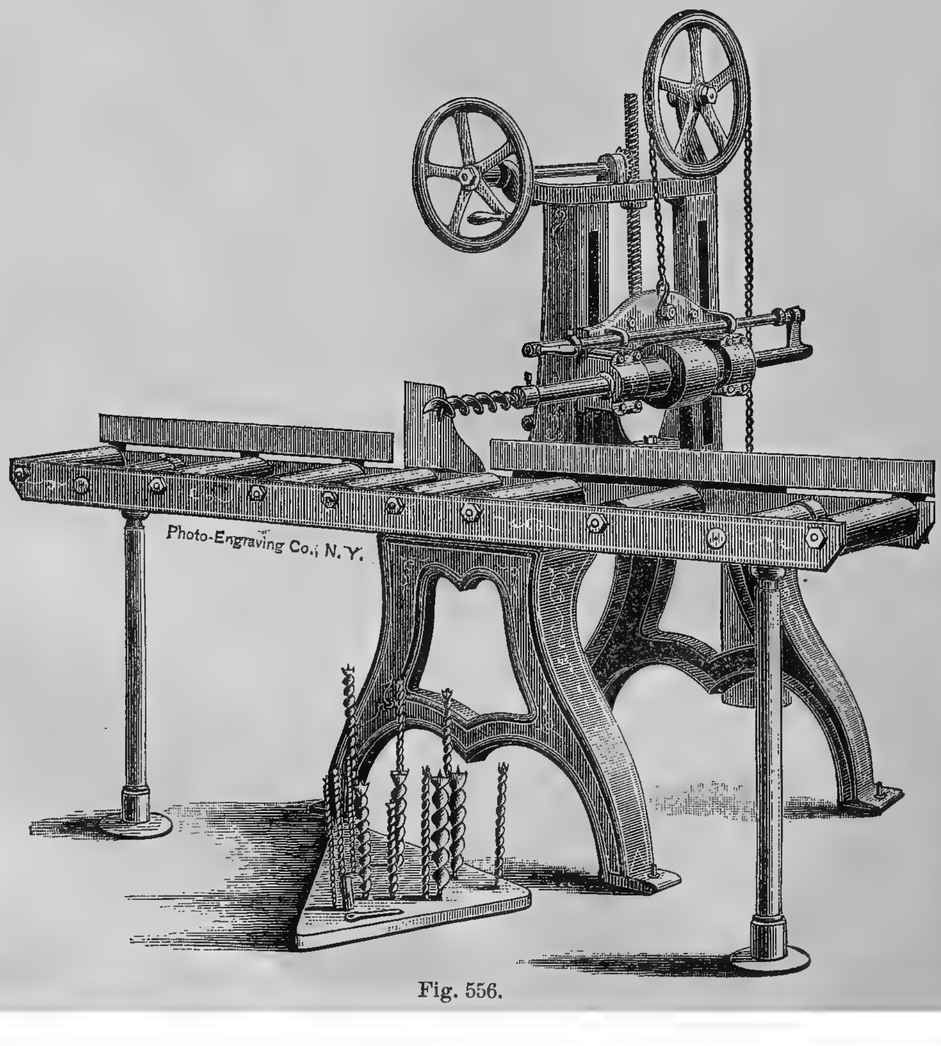

Fig. 556.

Figs. 558 and 559 are types of the vertical machines, which are driven by a belt over guide-pulleys. Provision is made in most of these machines for giving two or three speeds to the mandrels to adapt them for augers of different diameters. The tool is brought down to its work by a foot-treadle, so as to leave the hands free to hold the less stable work. The tables are adjusted easily, by rack and pinion in one case, and by a screw in the other The universality is attained by compounding the tables. In Fig. 558 the upper part of the table-upright rotates to any horizontal angle, and the sectors permit the table to stand at any angle with the horizontal or vertical planes through the bit. In Fig. 559 the table is gibbed to slides, and a double set of sectors is required. There are many smaller vertical borers which have the tables without universal capacities. Many of these have the table rise by a foot-treadle, or the spindle may descend.

The horizontal universal machines (Figs. 560 and 561) require no guide-pulleys, and the cone-pulleys may be on the mandrel. Stop-gauges or collars may gauge the depth of holes when the mandrel is pressed forward by the jointed levers from the counter-weighted treadle. Fig. 560 gives the angles by the screw with swiveling-nut. Fig. 561 is of the same design as the vertical boring-table by the same builders. A very usual type of horizontal

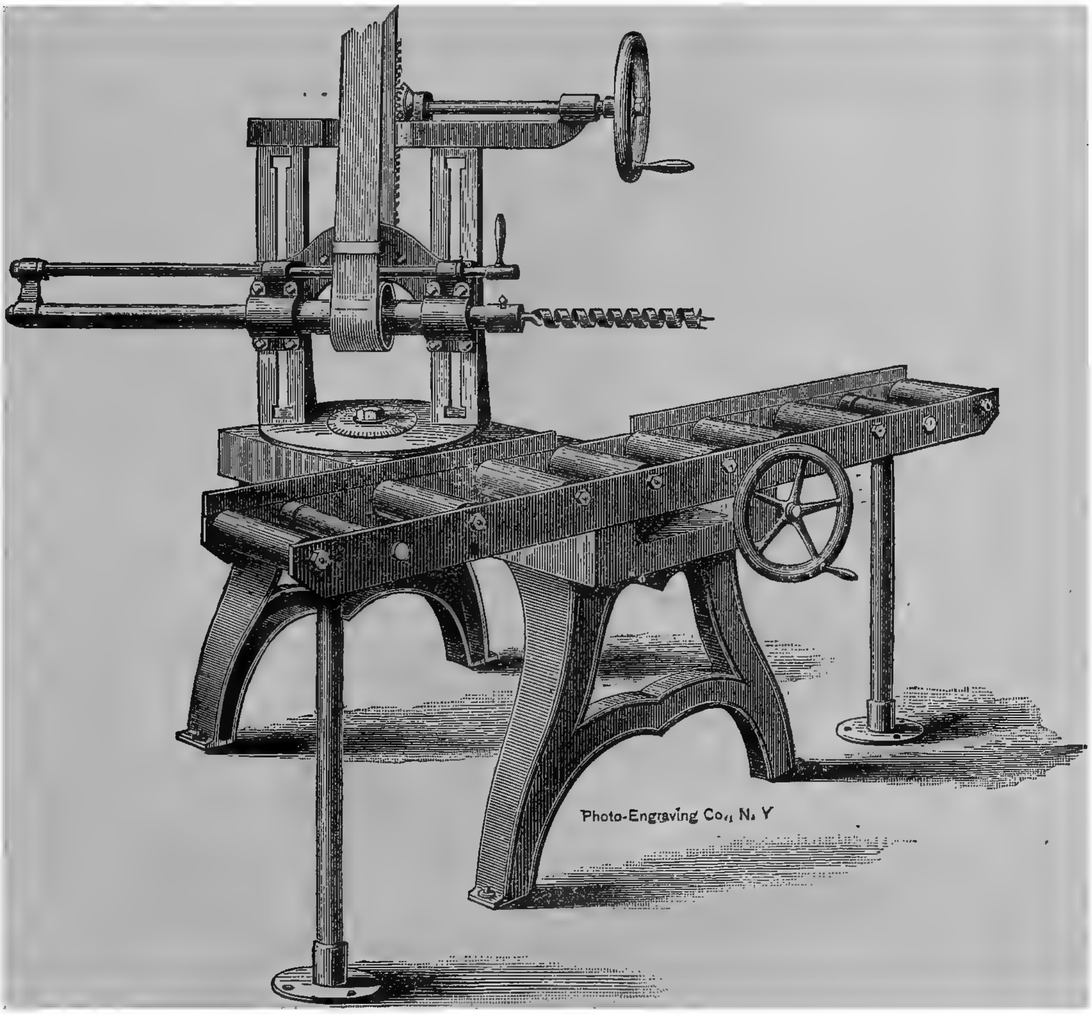

Fig. 557.

boring-machine is illustrated by Fig. 562. It is for work of medium size, and the vertical adjustment of the horizontal spindle is permitted by an arrangement of belt and guide-pulleys similar to that used on tenoning-machines. The tool is brought forward by a foot-treadle, acting by curved links upon the slotted lever at the back. The fence on the table is of hard wood.

In cabinet-work and in pattern-shops it is often convenient to bore two holes at once, at standard distances from each other, as for doweled work. A tool adapted for this duty is illustrated by Fig. 563. The two spindles are belted from the drum below, and are carried in two yokes, which are gibbed to the top of the frame. This top is shaped to an arc of a circle struck from the center of the counter-shaft, and the bits separate equally from a close central position by a right and left screw and hand-crank. The belts are always equally tense, and the fall of the bits as they separate is compensated for by lowering the table. The table rises and falls by the screw in front, and slides on gibbed ways to and from the bits. A stop-gauge below the table may insure standard depths.

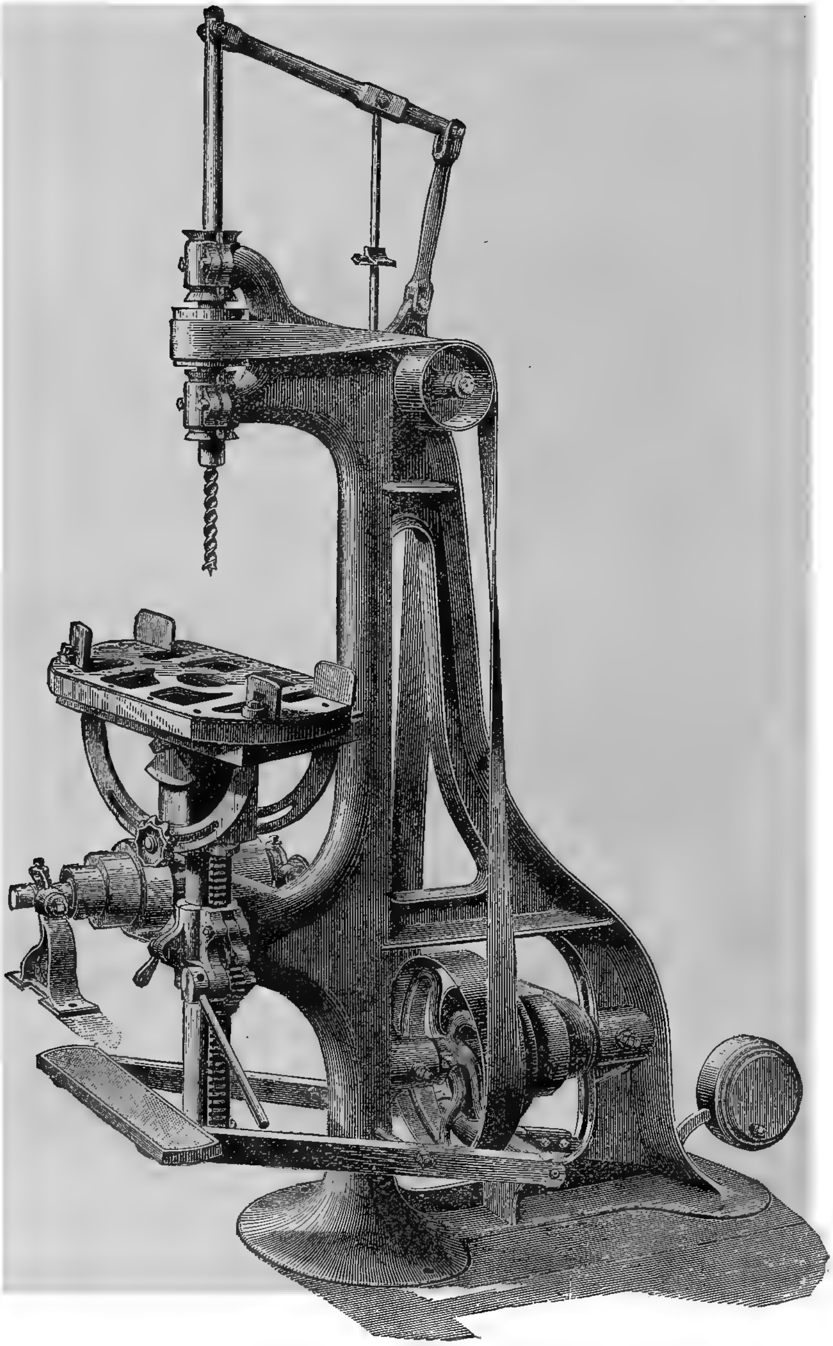

Fig. 558.

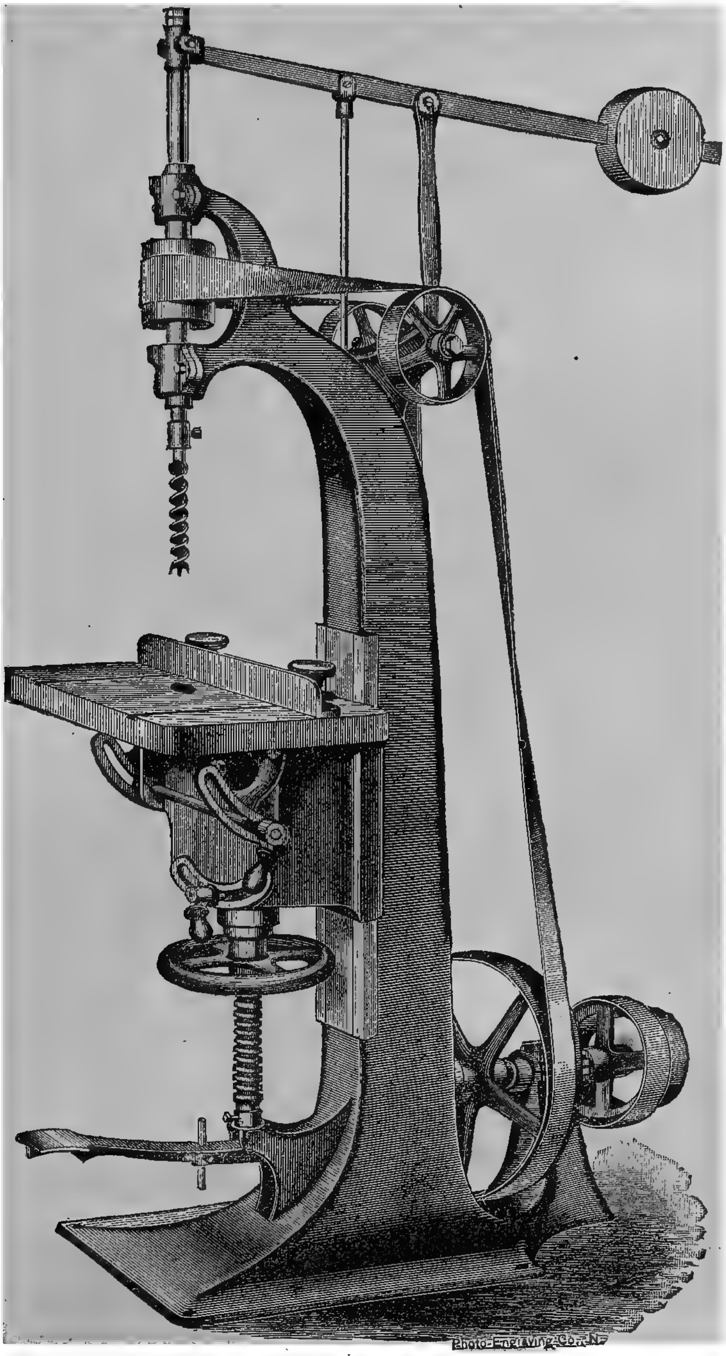

Fig. 559.

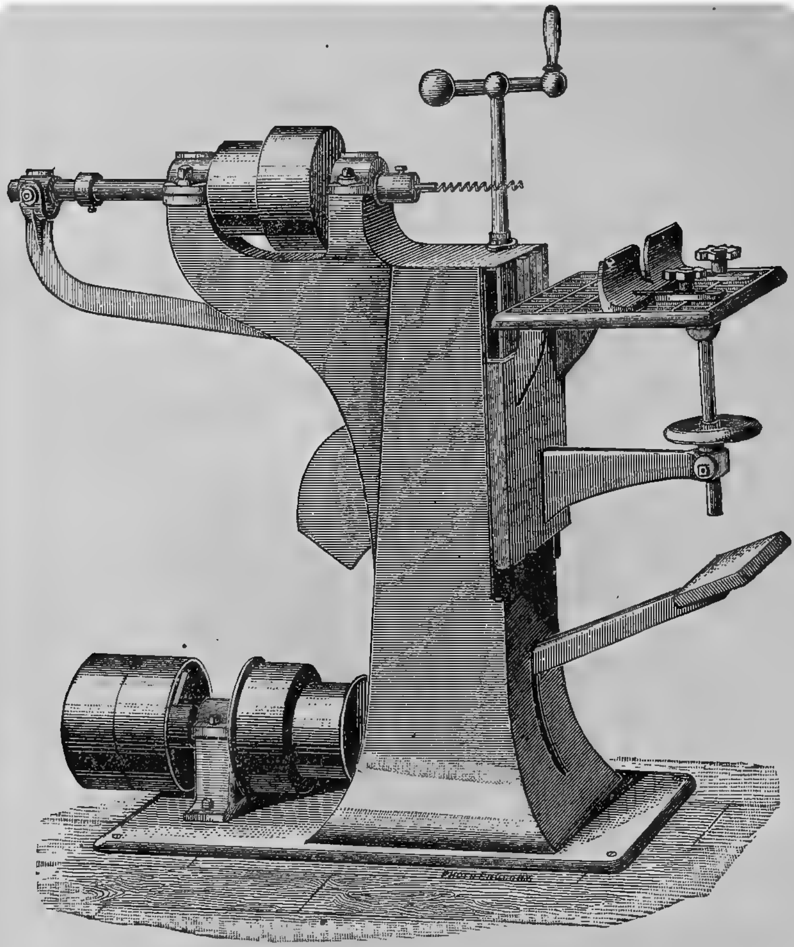

Fig. 560.

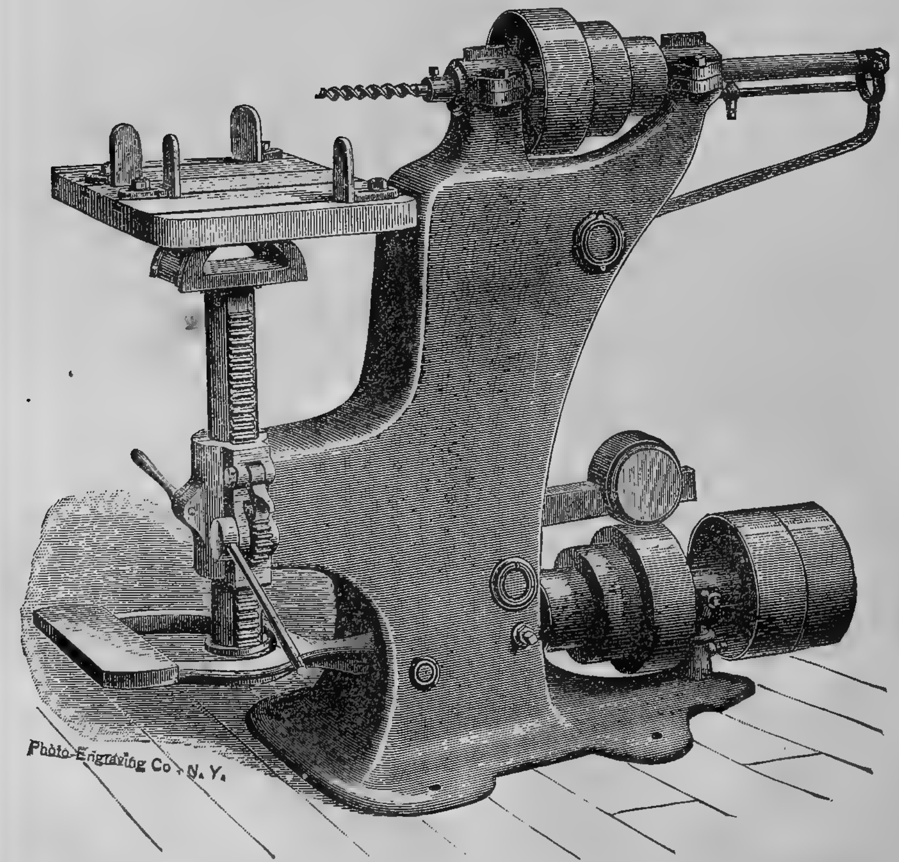

Fig. 561.

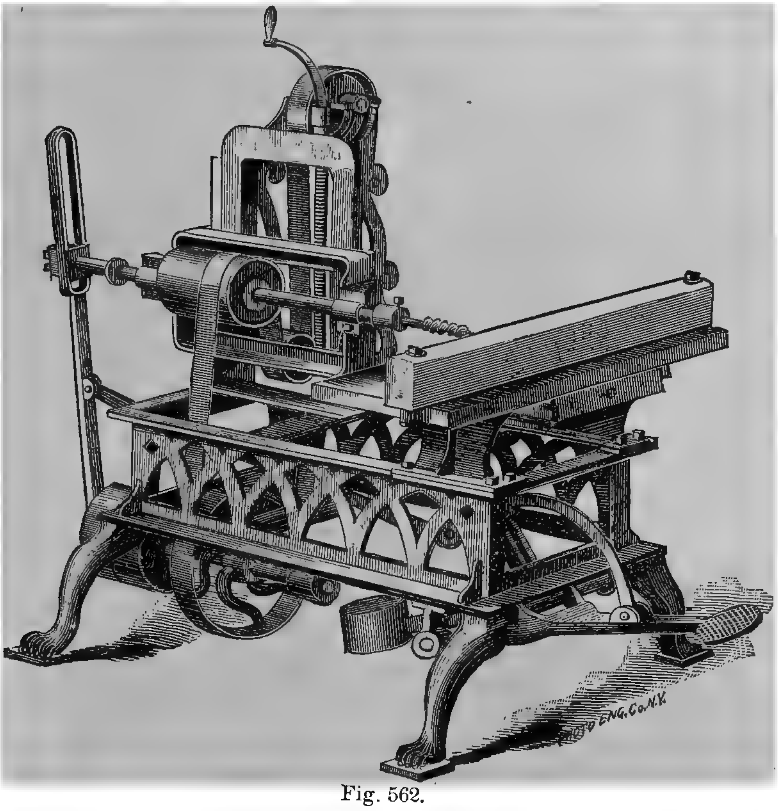

Fig. 562.

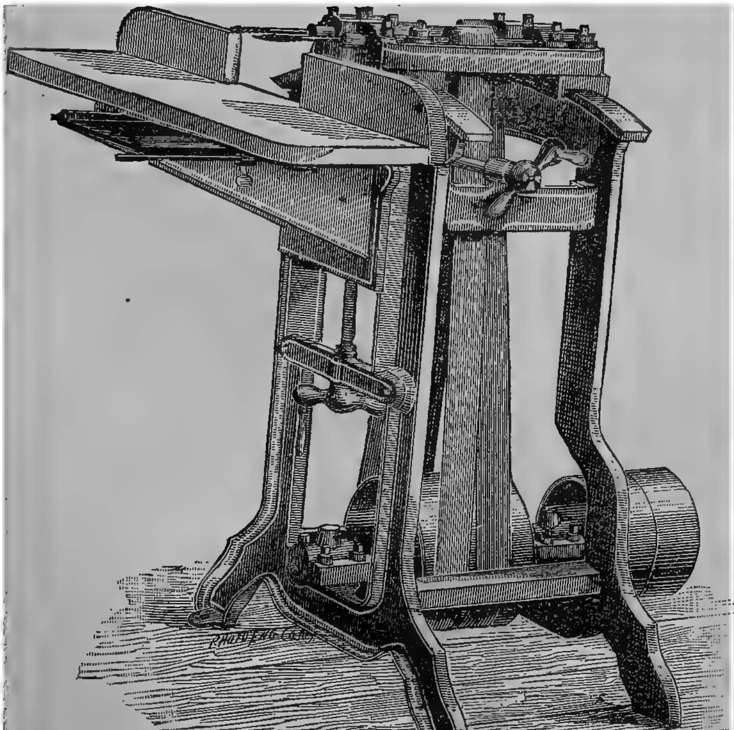

Fig. 563.

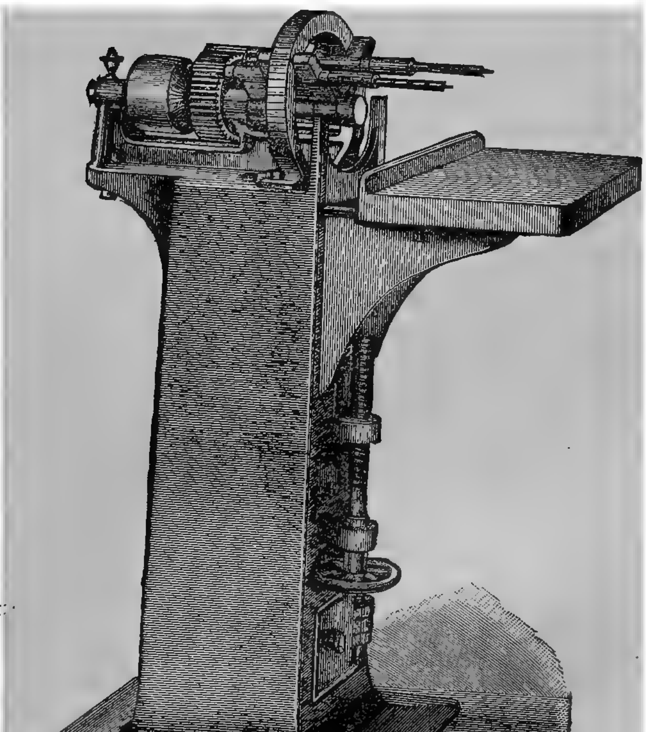

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Fig. 564.

Fig. 564 shows a similar tool, but it has the two spindles driven by long pinions driven by a gear, whose center is their center of adjustment. Not only can the bits be brought as near as the diameters of the pinions will admit, but the pair of holes may be drilled at any angle between the horizontal and vertical. The holes may be spaced from 1 inch to 6 inches from center to center. The table is adjusted by screw and hand-wheel, and there are two speeds for the spindle for convenience in the variations of auger and of wood. A tool of this same double class, which illustrates very clearly the close connection between the boring-machines and the rotary mortisers, is shown by Fig. 565. It is primarily designed for boring the holes in the stiles for rolling blinds, or for mortising

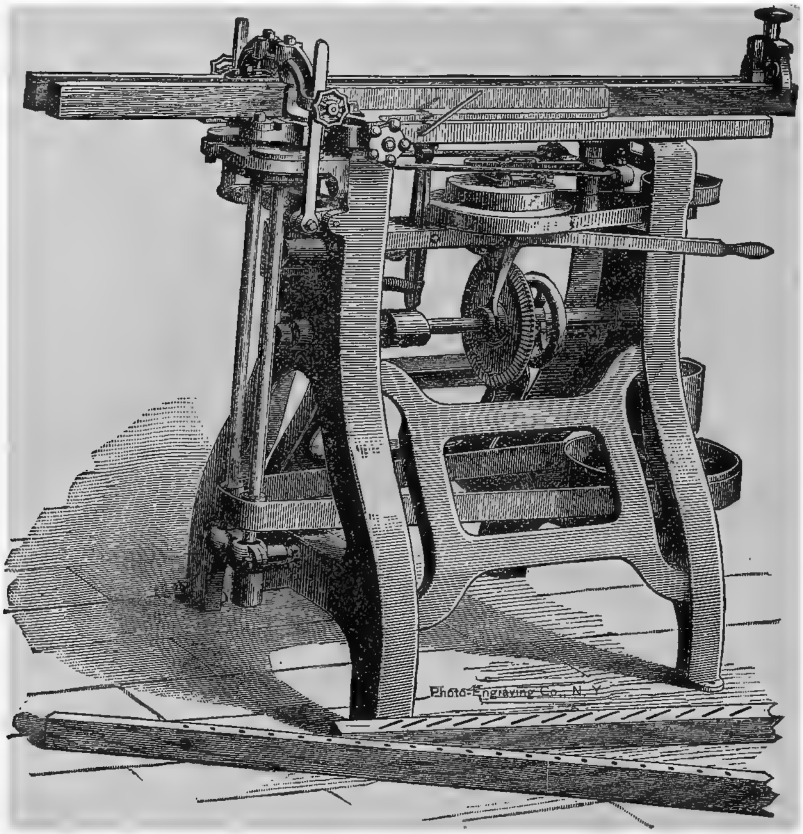

Fig. 565.

for fixed slats. Two stiles are received at once, and are fed vertically upward to a standard depth by a lever. The mortising motion is given from the wrist-pin on the horizontal disk, driven by the bevel-gear below. By releasing the clutch the tool is simply a boring-machine. The mortises may be at any angle with the length of the stiles, and their dimensions are controlled by stops. By making the cutters to work from below the holes clear themselves from chips, which might otherwise catch the cutter and break it. One hundred and fifty holes may be bored per minute, or 60 mortises may be made for stationary slats, and a manifest economy is thus effected.

The mechanical details of the boring-machines of to-day are of high grade. The spindles are of steel, and the thrust of penetration is borne by rawhide washers or by steel or composition steps. Many of them illustrate provisions to take up wear.

§ 55.

I.—MACHINES ACTING BY ABRASION.

SAND-PAPERING MACHINES.

The sand-papering machines correspond to the polishing-wheels for the metals. Their function is the production of a smooth surface upon the woods, that the varnish may produce an ornamental finish. For curved and cylindrical surfaces this power sand-papering has to be done by an endless belt. Upon this an adhesive like glue is spread, and sand or emery of the proper grit is dusted on the surface. There are usually mountings for two belts to employ two operatives and devices for maintaining the proper tension of the sand-belts. There is a great deal of grit and dust given off from such machines, and the boxes must be specially protected from the entrance of abrading particles. This type of machine is trying to the operators, but is required for some types of work. For flat surfaces, such as occur in door, cabinet, and piano-work, a bracket-machine is used such as is shown by Figs. 566 and 567.

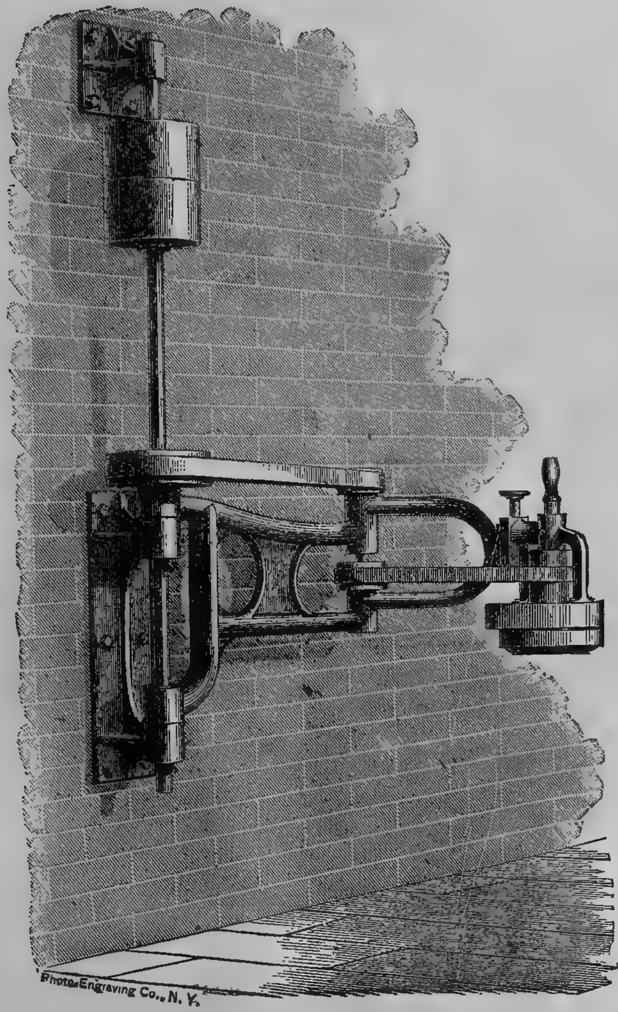

Fig. 566.

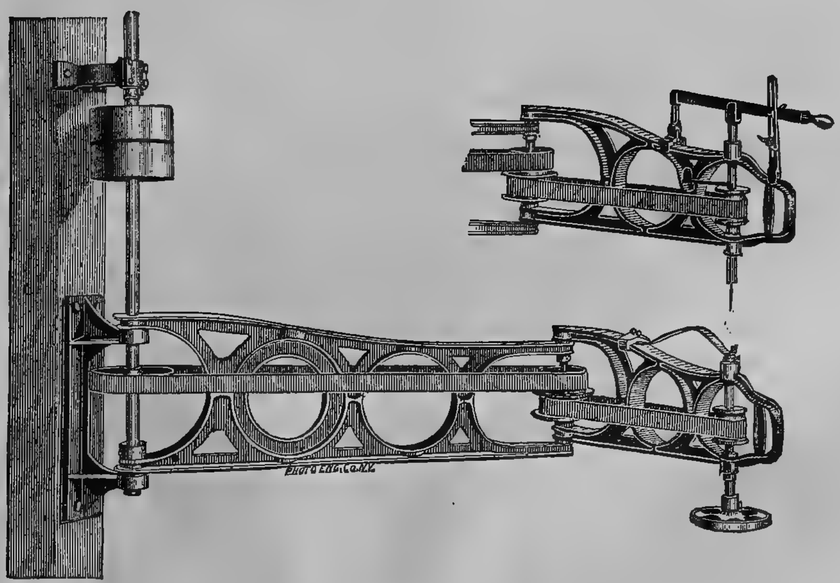

Fig. 567.

A vertical counter-shaft, with pulleys overhead or below the floor, drives a flat disk at proper speed. The bracket is divided to make an elbow-joint, with the pivot serving as idle shaft, to which the counter is belted and from which is belted the disk. This arrangement gives free motion to the disk in every direction. The adjustment of the disk for varying thicknesses is given by a milled-head screw, and the spring-handle of the disk enables the operator to gauge the amount of pressure. In the design of Fig. 567 the disk may be removed, and by a link attachment the spindle may be used for boring. The pressure of the spring is adjustable. A similar device has been applied for fancy wood-carving of large work. Where the work is unmanageable it is better than the system hitherto discussed. In Fig. 566 above the disk is an exhaust-fan on its side, and the arms of the bracket are hollow ducts, through which dust is carried away from the operator and his work. Scratches are less likely to mar the finish. Other designers put the fan on a separate mounting, with a special pipe to the disk, but this makes the arms more cumbrous.

For producing a smooth, even surface, without the circular markings of the bracket-machines, drum-machines are approved. Fig. 568 illustrates a type for hand-feed. The table is of wood, with steel lips. The cylinder is

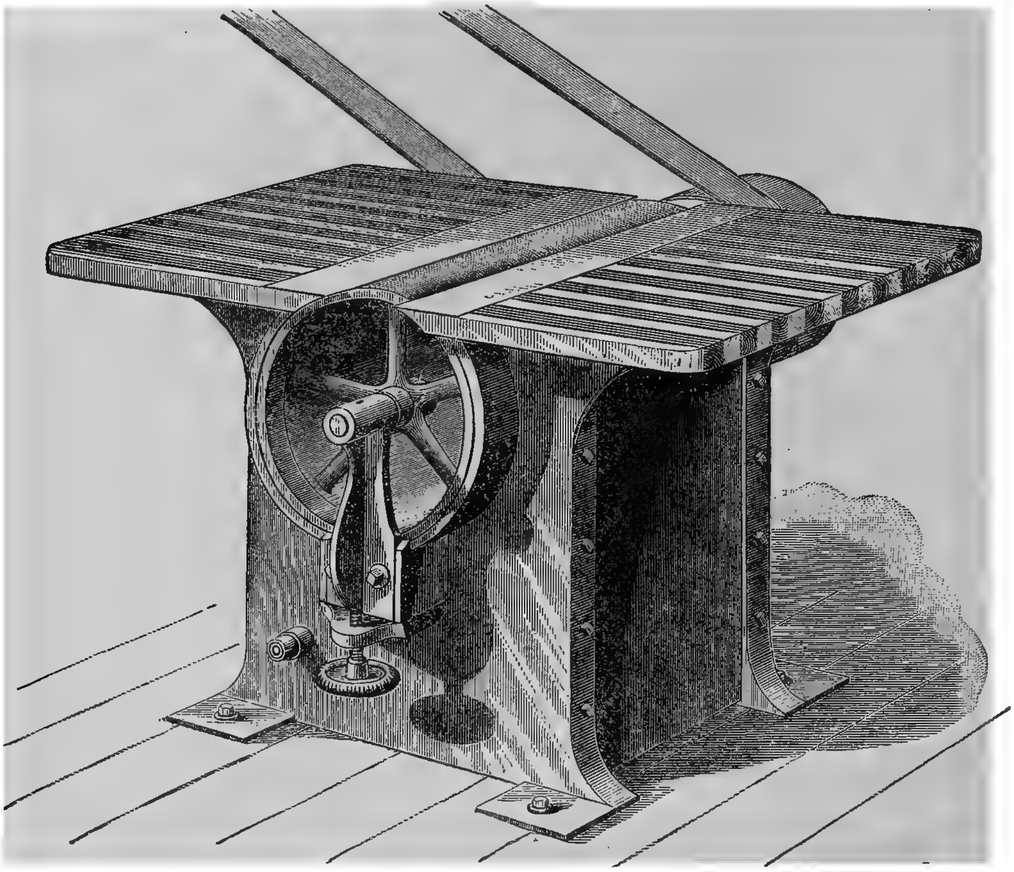

Fig. 568.

adjustable vertically, to regulate the amount of surface to be removed. The cylinder is covered with a flexible cover, which bears the abrading material. The box frame is nearly air-tight, and an exhaust-fan takes away the dust. There are advantages, however, in the regular feed when the gear is driven by power. Fig. 569 shows a machine where the feeding is done by rubber bands, driven by flanged pulleys and the geared rollers. The design of Fig. 570 has the feed given by pairs of smooth rollers, which are adjusted by screws connected by gearing-chain, and are driven from the cylinder through an idle belt-shaft. The elasticity for the pressure of the feed is obtained by rubber springs. For furniture, coffin, cabinet, and piano work these machines of the various types do much better and more satisfactory duty than can be done by hand-labor. They occupy an important place in shops which demand a high finish upon the work they turn out.

The emery-wheel has been recently applied to shape as well as to finish wood surfaces. A coarse or porous wheel—known as a "blubbered" wheel when vitrified—revolves rapidly against the work, which is slowly rotated. Hard woods especially are amenable to this treatment after the roughing-cuts of rapidly-fed machines. Whip-stocks have been smoothed by this process with marked success. But it may be laid down as a principle that unnecessary power is consumed when purely shaping processes must reduce to dust the material they remove.

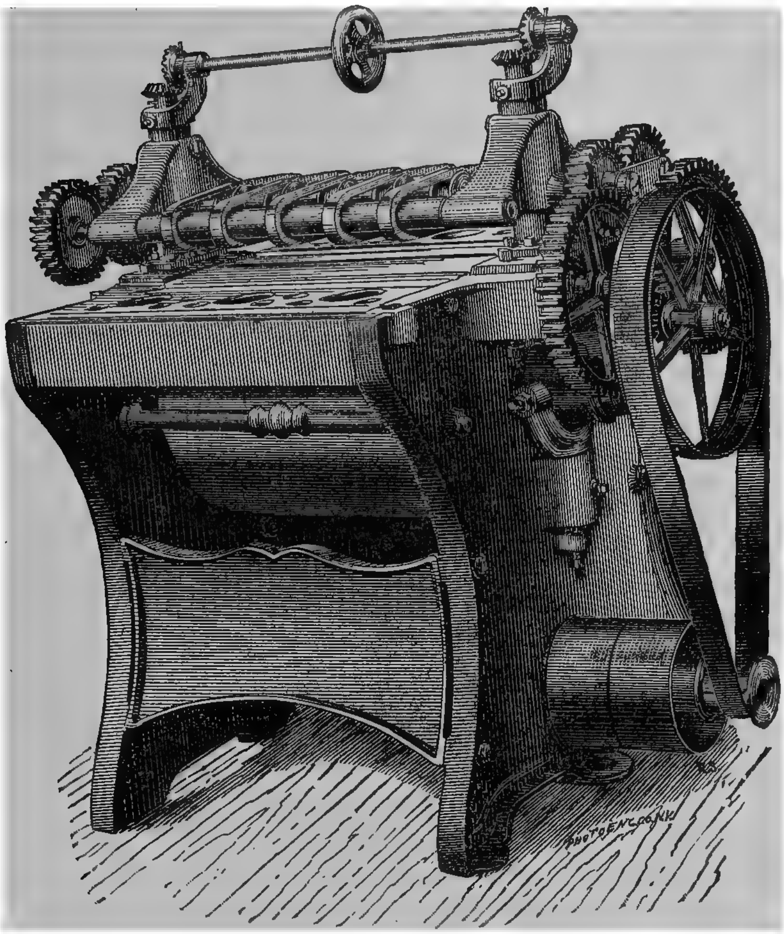

Fig. 569.

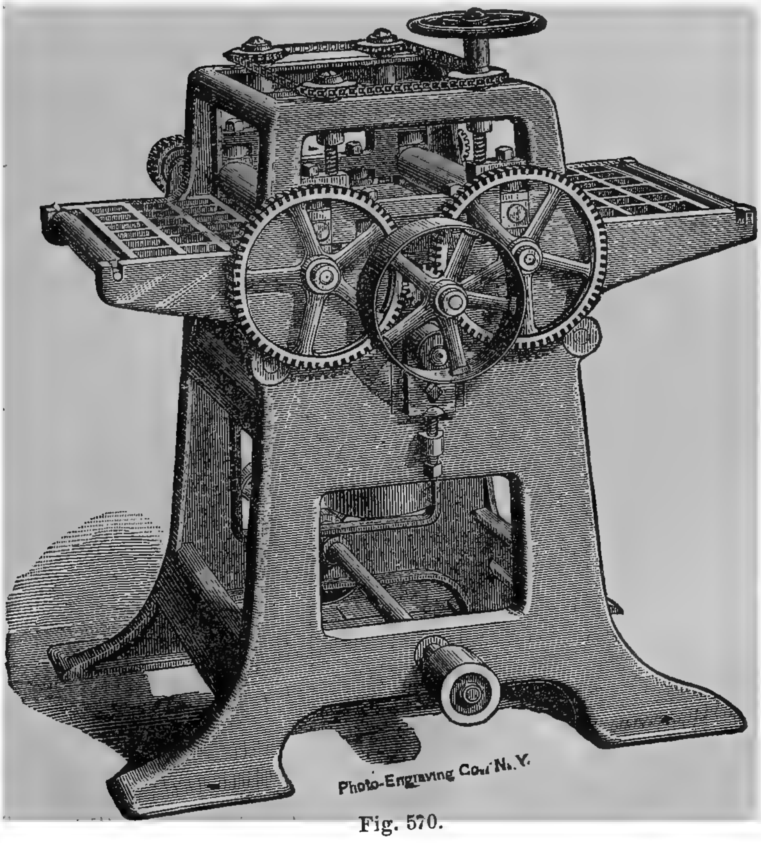

Fig. 570.

§ 56.

The same considerations have acted as in the first part to deter from detailed allusion to the linear capacities of the tools described. They are accessible to those who look for them. But it is difficult to leave the class of wood-working machinery without referring to two points, which are indicative of recent progress. The first is the change by which the manufacture of this class of machine has passed from the hands of wood-working operatives into those of mechanical engineers. The first machines were built with wood frames, and were open to all the objections which follow from the use of a material which is elastic and is susceptible to atmospheric influences. The newer machines are more deserving of their name. They are built of steel and iron, by specialists in their manufacture, and with the same care in fitting which is called for in metal-working tools. A much higher grade of work must result, which will favor successful competition in critical markets. The second point to be noted is in part a consequence of the first. It is the gradual increase in speed of feed, and the capacity for enlarged output, due to that increased speed and to better construction. The increased output makes it possible for the purchaser to pay for a better machine, and the better machine cheapens the product by a wider distribution of the interest account and of the diminished repair account. In the earlier days the excuse for the purchase of cheap machinery was that new improvements would make it necessary to exchange old tools before they had paid for themselves. Tool-builders must always meet the demand for the grade of machine wanted, and these two causes interacted. But of later years, the better judgment of consumers, and the more advanced skill of specialist builders, has given an impulse in the direction of true progress, and the engineering community is realizing more fully the truth of the old aphorism, "the best is the cheapest".

INDEX TO MACHINE-TOOLS AND WOOD-WORKING MACHINERY.

T.

V.

W.

REPORT

ON

STEAM-PUMPS AND PUMPING ENGINES,

BY

F. R. HUTTON, M. E.,
SPECIAL AGENT.

TABLE OF CONTENTS.

Part I.

Part II.

Part III.

PART I.

STEAM-PUMPS.

INTRODUCTORY.

A steam-pump is a steam-engine whose load is the resistance due to the work of displacing fluids under a pressure or head. Hence the distinction between the steam-pump and the pumping-engine must be entirely conventional. By common consent, the term "steam-pump" is applied to the smaller engines whose work is subsidiary to that of a large establishment. The term "pumping-engine" is restricted to those larger and more elaborate designs, where the amount of fluid to be displaced is so large that the pumping machinery becomes of primary importance. The "pump" of a water-works, of a mine, or of a sanitary enterprise then becomes a "pumping-engine".

Following this purely arbitrary and conventional division, the class of steam-pumps will be discussed first.

The class of steam-pumps naturally divides itself into three sub-classes:

A. Reciprocating pumps.

B. Rotary pumps.

C. Direct-contact pumps.

Each of these has various subdivisions, under one or the other of which all the different forms can be included.

2

STEAM-PUMPS AND PUMPING-ENGINES.

PART I.

Class A.—RECIPROCATING PUMPS.

The class of reciprocating steam-pumps includes all those in which there is an alternate motion of a piston in a steam-cylinder. This motion is communicated by a rod to another piston or to a plunger, which displaces the fluid that enters its cylinder through the valves at either end alternately.

For convenience of discussion, these pumps may be classified as follows:

I. Crank and fly-wheel pumps.
II. Direct-acting pumps.
III. Duplex pumps.
IV. Cam pumps.
V. Spring pumps.

The most essential differences in these pumps are caused by the differing methods for controlling and actuating the steam valves. They have many parts and features so much in common that it seems wise to note them first, and to pass afterward to the points of divergence.

All have a steam-cylinder, truly bored, and fitted with the piston upon whose alternate sides the steam is to act. To compensate for wear and for expansion, this piston has to be fitted to the bore of the cylinder by packing-rings, which shall by their elasticity prevent leakage of steam from one side of the piston to the other. In some cases, plain cast-iron rings are used in grooves in a solid piston, the elasticity of the rings themselves serving to keep the rings in contact with the bore (Fig. 49). They are turned a little too large for the bore, a diagonal cut is made at one point, and the rings are sprung in place. Other makers use steel or brass rings, similarly made (Fig. 1). Others again put a brass spring-ring inside the packing-rings proper, to force them outward (see Fig. 6), while a few use manufactured packings of some fibrous and elastic materials, such as canvas and rubber. In a few cases, also, the regular locomotive-piston principle is used (Fig. 2). The piston consists of piston and follower bolted together, the rings being forced out by elliptical springs between the arms of the spider. The springs are adjustable between jam-nuts upon studs, to vary the pressure upon the double set of rings. A few use spiral springs (Fig. 56), and steam-packed pistons are also in use (Fig. 3).

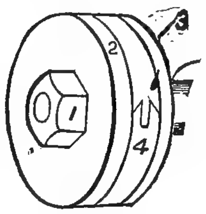
Fig. 1.

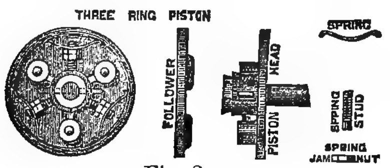

Fig. 2.

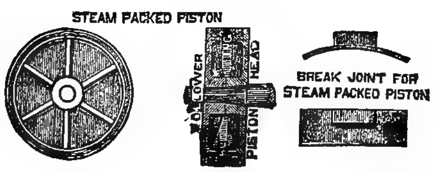

Fig. 3.

The steam-piston is secured to the piston-rod, in the great majority of cases, by a nut (Figs. 1 and 7). The end of the rod is tapered and threaded, and a nut secures all in place (Fig. 56). In a few instances the end of the rod is headed over so as to rivet the piston in place, but it is usually thought desirable to have the joint between them more easily broken.

The piston passes out through a stuffing-box in the steam-cylinder and through a similar stuffing-box into the water-cylinder. Fibrous or manufactured packing is used in these stuffing-boxes, metallic packing not having been applied upon a large scale as yet. The glands are tightened by two bolts almost universally, these bolts being so disposed that the sides of the cradle shall not interfere with the wrench which should turn the nuts upon them. For valve-stem stuffing-boxes the cap-nut over the gland is very general (Fig. 4). One or two only use that arrangement for the piston-rods.

In the water-cylinder there will be either a second piston fitting the bore (Fig. 45), or else a plunger of less

diameter than the bore, fitting a gland (Fig. 54). Circumstances must determine which will be best for any given case. When the water is dirty or gritty, a piston sweeping over the silt in the bottom of the cylinder wears out both surfaces rapidly. A plunger protruding through a stuffing-box tends to free itself from solid particles, and the bore of the cylinder is untouched. A piston-pump has a small clearance volume, and therefore can lift water from a depth more rapidly than a plunger-pump, where there is much more air left in the cylinder to expand after each stroke. The plunger acting by positive displacement is well adapted for forcing under high heads and resistances. On small short-connected pumps the plunger is often single-acting, lifting and forcing alternately. In larger pumps, the water-end is in two parts, with stuffing-boxes facing each other in the opening between them (Fig. 35). The plunger moves in and out of each, driven by a rod through the inner head. This necessitates three stuffing-boxes. In another arrangement there are two plungers, connected together by rods upon the outside. The plungers enter the water-cylinder through glands at each end, and there is a partition in the middle so that the lifting and forcing may be continuous. Another plan is to have one plunger passing through a gland in this partition in the middle of the water-cylinder (Fig. 54). The piston-rod is attached to one end of the plunger, entering the water-cylinder through a stuffing-box. The two halves of this cylinder will therefore be filling and emptying alternately, producing thus a continuous flow. If elastic packing is used for the gland in the partition, it is apt to make the plunger wear small in the middle where its surface is most frequently rubbed. It is also difficult to tighten the gland if there is leakage. Some prefer an inelastic metallic ring closely fitted.

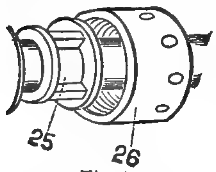

Fig. 4.

A further advantage of the plunger system is that the area of the water-plunger can be varied relatively to the area of the steam-piston without involving the change of the whole water-end of the pump. This change in relation of areas may be called for by increased or by diminished head or resistance upon the delivery. Plungers of different diameter can be introduced, and nothing but glands and stuffing-boxes need be altered. Moreover, to turn and fit the plunger and the glands when worn is much easier and cheaper than to disconnect and re-bore the cylinder. The plunger is much lighter and more portable than the cylinder and attachments, and also where resources are limited, outside turning is more feasible than inside boring. One designer combines the piston and plunger arrangement in what is known as the bucket-plunger pump (Fig. 5). The part of the piston-rod which

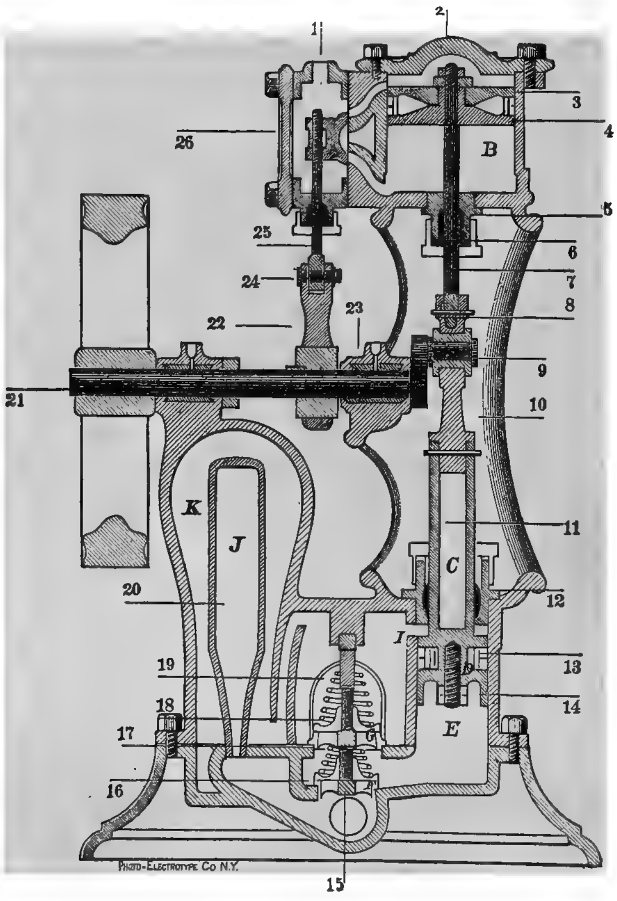

Fig. 5.

enters the cylinder is a plunger of one-half the area of the piston. The whole volume of the cylinder is filled from the suction upon the upward stroke of the piston. Upon the downward stroke, this water is discharged through the delivery valve. The upper end of the working barrel is in direct communication with the delivery-passages, so

that one-half the capacity of the cylinder enters above the piston around the plunger, the other half only being forced into the pipes. On the upward stroke the piston displaces the water above it, and fills again below. The pump is therefore single-acting in sucking, but double-acting in forcing. It delivers one-half the capacity of the cylinder at each stroke. To accomplish a similar purpose, and at the same time to avoid any change of direction of the currents of water, is the object of the tubular pump shown in Figs. 6 and 7. At the extreme left is the

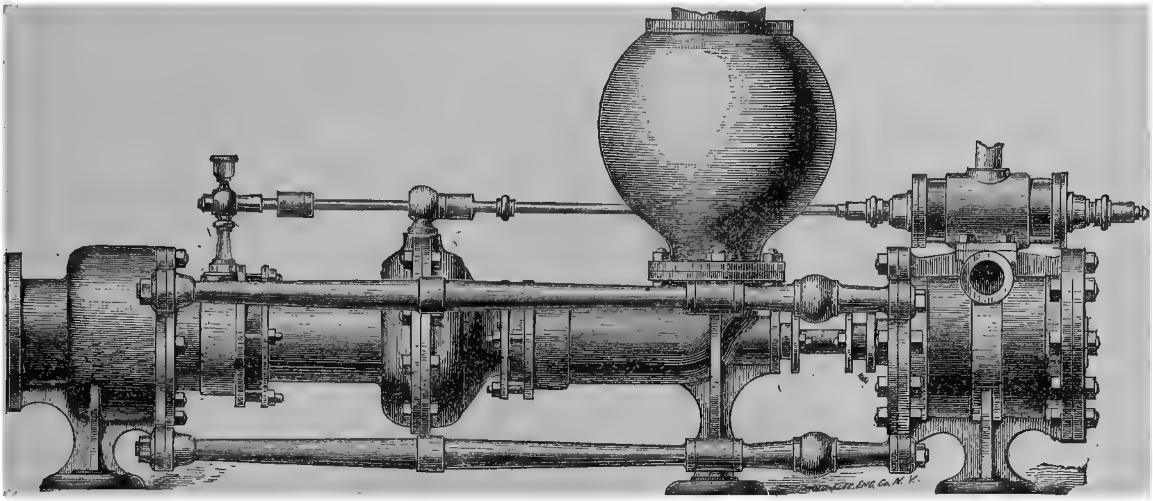

Fig. 6.

large foot-valve on the suction-pipe, through which the fluid enters and fills the large hollow plunger A, up to the central valve. Upon the return of this plunger the central valve is opened and the fluid passes into the smaller tube B. The capacity of B is one-half that of A, and hence the excess must pass out through the discharge-pipe.

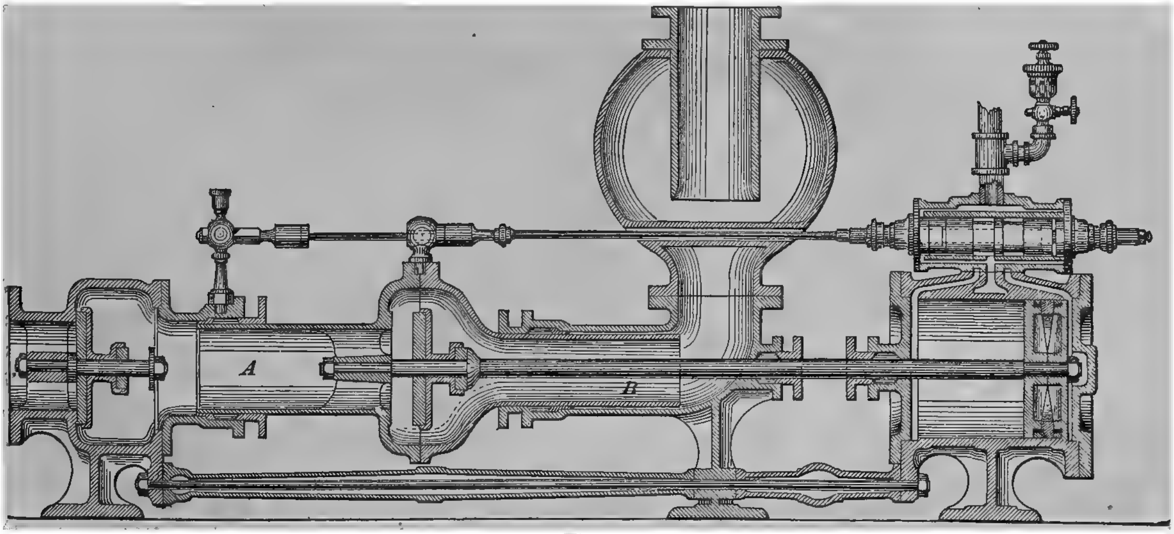

Fig. 7.

Upon repeating the first stroke, the volume of the smaller tube B is again displaced while the larger tube is being filled. Hence the capacity of the pump at each stroke is that of the smaller reciprocating tube.

For the packing of water-pistons, either cup-leathers (Fig. 8), square rubber (Fig. 9), or some of the patent

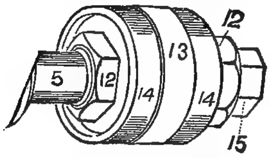

Fig. 8.

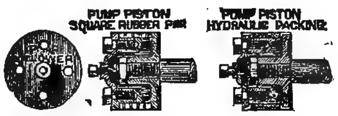

Fig. 9a.

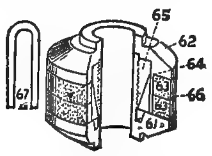

Fig. 9b.

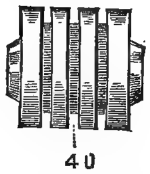

Fig. 9c.

packings are preferred. Brass rings are sometimes used, especially for hot water or acid pumps, and in many cases simple grooves are turned upon the surface of the piston (Fig. 9*c*). These grooves fill with the fluid being pumped, and prevent any leakage from one side to the other during a stroke. This form of piston depends upon the principle that a fluid leaking into the first groove through the small passage between piston and bore must there accumulate pressure before it will leak into the second groove through a similar small passage. The groove, being

relatively large, requires an appreciable time to fill, and the piston will have made its stroke before all grooves are filled, and leakage begins into the suction side. For the plunger stuffing-boxes, elastic fibrous or manufactured packings are preferred.

There must be two sets of water-valves at each end of the cylinder of a double-acting pump. One set must open upon the lifting-stroke at each end, and the other set must open upon the forcing-stroke. With respect to their position relatively to the barrel there are four types of practice. In one case they are put at the side of the cylinder (Fig. 49), in the second upon the top (Fig. 10), in the third upon the ends, and lastly on both top and bottom. The

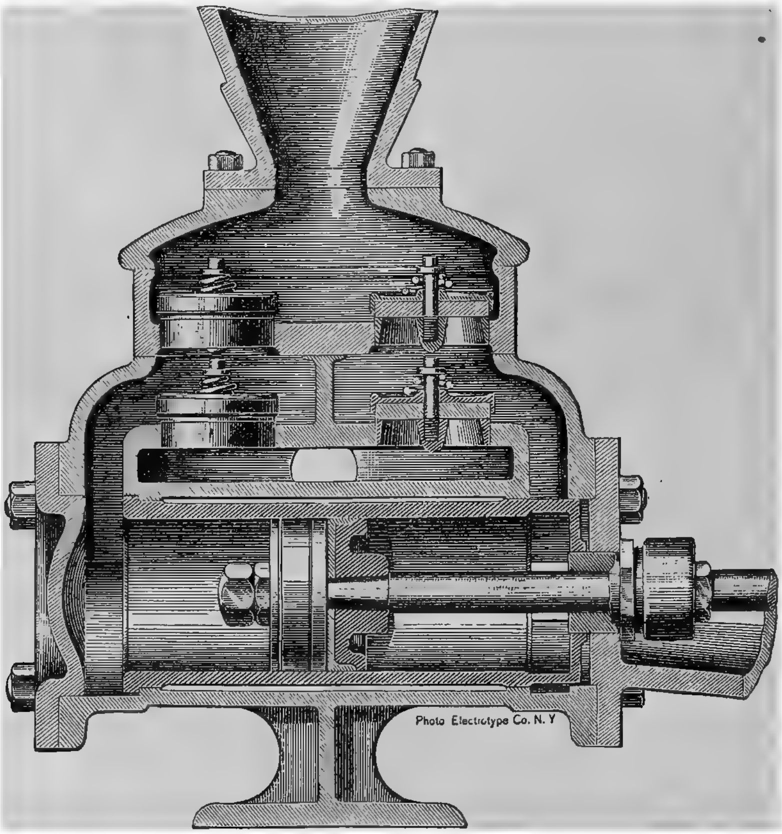

Fig. 10.

suction-valves are nearly always put directly under the delivery-valves (Fig. 10). The space between the two connects with the pump-barrel at each end, and a partition separates the sets which act on the forward and backward strokes. There is but one design having the valves in the cylinder-heads (Fig. 46). A great deal of attention has been paid to the matter of removable bonnets to permit easy access to the water-valves for cleaning and repair. In the forms where the valves are upon the side of the cylinder and the stroke is short, the whole side of the casing can be taken off (Fig. 49), being secured by stud-bolts and nuts. The bonnet and chamber surfaces are faced and the bonnet is recessed, so that a joint may be made water-tight without a gasket or other form of packing. Where the stroke is longer, the bonnets are often faced disks opposite each pair of valves, secured by studs like a cylinder-head. In one form the valves are in tubular chambers at each end, which can be opened by taking off their lids (Fig. 35). These lids are either screwed plugs or bolted covers.

Where the valves are on the top of the cylinder there must be differences according to the construction. In many forms the suction-valves are in a flat plate directly above the cylinder. Upon this plate fits a box. The delivery-valves seat upon a partition in this box, and over all fits the cap of the pump carrying the air-chamber. In other forms a plate for the seating of the delivery-valves covers the solid box in which are the suction-valves, and the cap fits close upon the plate (Fig. 32). In another type the seatings for both sets of valves are cast with the cylinder, and the lower valves and removable seats are put in place through the upper plate (Fig. 42). The cap, as before, fits on this top plate. This, of course, avoids one joint. In any of these latter cases the removal of the whole cap permits access to the valves. It is held down by tapped studs and nuts, or else in newer practice by eye-bolts, which swing out and down out of the way when the nuts are loosened (Fig. 34). The bolts and nuts cannot be mislaid or lost, as none are removed altogether from pump or bolts, and the nuts need be unscrewed but a little to release the cap. An especial point with regard to these bonnets is that they shall permit access to the valves without causing interference with the piping to or from the pumps. In the larger pumps with this type of water-end, separate bonnets are called for, because of the size and weight of the caps.

It is practically universal to use inserted valve-seats for the water-valves (Fig. 10). These seats are brass gratings fitted to the casting of the cylinder either by being screwed, keyed, or forced into place, or else are held in

place upon a ground surface by a cage or the valve-spindle. The practice of screwing in the seat is objected to on the ground of the tendency of such seats to work loose, permitting corrosion of the threads. Forcing or driving them in place is more usual, the castings being bored with a slight taper. In a few cases, after screwing or forcing the seat into place, a taper pin or key is driven in to prevent loosening from the shocks of the valves and water. There are advantages in favor of the ground-joint with cage or spindle to hold the seat in place. The valves must be over each other. After the lower seat and valve and spring are in place a brass cage is put over the valve, guiding the spindle (if any is used) and resting upon the seat outside of the valve. This open cage is held in place by the bottom of the seat of the upper valve, and is thus kept from moving. This upper valve-seat is kept down by a similar cage, which is held from rising either by a key driven between the cage and a boss on the casing (Fig. 5), or else by the end of a bolt tapped through the casing from the outside (Fig. 56). Where, as is frequently the case, this bolt is in the center of the bonnet, the removal of the bonnet loosens all the valves and seats and permits easy inspection or renewal, whether the defect be of valve or of seat. This replacing of a seat cannot be so readily done in other arrangements. In some forms the seats are held in place by a spindle which enters a step in the lower seat, and has a collar or shoulder to secure the upper seat (Fig. 49). Some secure the lower seat, and have the shouldered spindle screw into the center of the lower seat, thus confining the upper. The valves are then independent of the cap.

Rubber is used almost universally for the valves themselves in cold-water pumps. Many purchasers prefer brass for valves in hot water, but a large number of makers are using a rubber composition made for this purpose, and especially hard and resistant to heat. The small rubber valves are simple disks with a hole in the center through which passes the stationary guiding spindle (Fig. 12). This spindle is often a simple brass bolt, screwing into the seat. Its head serves as abutment for a spiral brass or steel spring which presses upon the top of the valve to prevent it from rising too high and to close it promptly. Where there are cages there need be no spindle, or if there are shoulders upon a long spindle they may receive the thrust of the springs. In some of the larger valves the back of the valve is reinforced by a metallic plate or grating to receive the greater pressure of the spring and to stiffen the valve. The back of the valve is either specially shaped to retain this plate, or else the valves are moulded around it by the manufacturer.

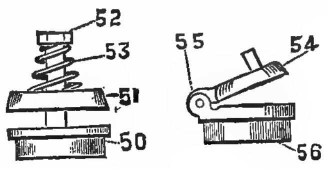

Fig. 12.

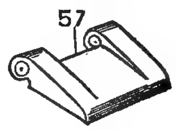

Fig. 13.

Brass valves have their guiding spindles cast with them, sliding in a caging either above or below the valves, or both. There are very few makers who use any other form of valve. Two use a hinged valve of rubber with metallic backing (Fig. 13), and one uses square prisms guided by the walls of the casing (Fig. 36). There is a wide divergence of practice with respect to the area of the valve-openings relatively to the piston-area. In some cases the valve-area is only one-third of the piston-area for low-speed pumps. In other patterns the valve-area is one-half, six-tenths, or two-thirds of the piston-area. The newest practice where patterns have been changed and improved is to give a valve-area equal to that of the piston or even greater, especially in pumps for high speed. This avoids the high velocity and pressure through the valves, permitting a less lift, and causing less jar in the seating. It is also more certain that the barrel will be filled at each stroke.

There is no less divergence with respect to the number and the diameters of the single valves which make up the aggregate area. Some use several small valves, three inches in diameter or less, while others prefer a few valves of large diameter, using eight-inch valves in some cases. There are advantages connected with each system. A disk-valve can be shown, by a simple calculation, to be able to discharge its maximum quantity when it has risen from its seat a distance equal to its radius. Then the area of the cylindrical opening between valve and seat will be equal to the area of the circular opening of the seat. In theory, therefore, a large valve should lift farther from its seat than a small one if the passage of the water is not to be impeded. But a high lift of water-valves means a loss of efficiency from leakage before the valves close; and also there will be violent shocks from the blow of the valve as it is brought up against its seat by the outrushing water. These shocks will loosen all joints and wear out all connections. High lifts of valves are, therefore, to be avoided to insure quiet working, and this is to be attained by the use of small valves where the lift can be very much reduced without loss. The small valves on the suction side act as a strainer to prevent large obstructions from reaching the cylinder, where they might do great harm.

On the other hand the use of few valves reduces the number of parts in a pump, reduces the amount of space required for the valves in the water-end, permits easy and direct access to all valves when the bonnets are removed, and diminishes the chances for leakage of valves by diminishing their number.

Average practice for small pumps will be found to favor one or two valves for suction and for delivery at each end of the cylinder, of a diameter suited to the capacity of the pump, lifting from three-sixteenths of an inch to five-eighths, according to size and speed of the piston.

The air-chamber is an almost universal feature of the water-end of a steam-pump. The only exceptions are found in a few boiler feed-pumps, where the resistance to the plunger is an elastic tension of steam, and in some of

the forms of plunger mining-pumps. The function of the air-chamber is to serve as an elastic cushion to start gradually the motion of the water-column from rest, and also to keep up the flow steadily from the delivery-pipe by the expansion of the imprisoned air.

Upon horizontal pumps the air-chamber is carried upon the top of the water-chamber, either cast as part of the lid of the valve-chest (Fig. 37) or bolted or screwed to it (Figs. 10 and 45). When screwed to the lid it is often made of copper. There is, however, great variety in form, from the cast- or wrought-iron cylinder with rounded or flat top (Fig. 14) to the spherical globe (Fig. 46). The prevailing form is the conical with a rounded top (Fig. 47), passing into an elongated pear-form in some designs. This form is easy to secure to the cap, and offers a larger water-surface to the inclosed air. In the designs where the valves are reached through bonnets, the delivery-pipes start from the base or the neck of the chamber. Where the whole cap is removed, the pipes have to be connected to outlets from the cylinder casting below the joint with the valve casing, otherwise a pipe-joint must be unmade in order to obtain access to the valves. An air-chamber on the suction-pipe (or a vacuum-chamber, as it is often called) is sometimes added, where the mass of water in the suction-pipe is considerable (Fig. 38). This will be the case with high lifts, or where there are long reaches of horizontal pipe through which water passes to the pump. The vacuum-chamber will also be judicious where the water is delivered to the pump under a head or at high speed. Its object is to bring to rest the moving mass of water when the suction-valves close, without jar to pipes or valves. The inertia of the column is arrested gradually by the air-cushion in the vacuum-chamber instead of expending itself all at once in a blow against the valves. Hence it would seem that the most expedient place for this chamber would be close to the valves, and in a prolongation of the direction toward which the water was moving when the valves closed. In this situation it will be most efficient. Very often, however, this chamber is simply a long plugged nipple from a T in the suction-pipe and at some distance from the valves. One maker casts the bonnets and walls of the suction volume of the water-end with large recesses in them (Fig. 17). These are filled with air, and being close to the valves would appear to be very efficient for the purpose intended.

Certain modifications are made upon the typical forms to adapt the pumps for special duties. The usual relation of areas of steam-piston to water-piston is as one is to three or four, for tank or general purposes. This will be varied according to the head against which the pump is to work. For air-pumps the ratio will often be reversed. For acid or mine waters, a removable lining will be used in the water-end of brass composition, or copper, or other non-corrodible metal. This lining is secured in place in a variety of ways. In some cases it is cast with a flange at one end, of which the holes fit over the studs in the cylinder-flange, and the cover holds all in place. Ports in the bore of the lining permit the water to pass into the passages to the valves at each end. It is important in this arrangement to have the studs equidistant, in order that the lining may be revolved in place so as to expose a fresh part to the wear of the grit on the bottom by the piston. Another arrangement is to secure the lining to the inner head (Fig. 10). A boss threaded on the outside passes through the head, and a nut and gasket on the outside clamp the lining to the head. The boss forms the stuffing-box for the main rod. The other end of the lining abuts against a counter-bore near the outer cylinder cover. Still another way is to insert a plain cylinder, and after it is in place to expand it by blows from a hammer upon the bore. This pening stretches the inner skin, enlarging the diameter and making the contact with the iron very close. For plunger-pumps this needs no further treatment, but for piston-pumps the bore is trued out by a very light cut, which does not go sufficiently deep to release the strain of the skin.

Further minor modifications will be called for by special industries. To pump active acids will require a pump entirely of composition; to pump ammonia demands a pump entirely of iron. Often an air- and water-pump will both be driven by the same piston-rod. Several makers have put upon the market a vacuum-pump in which the acting piston is a surface of water which is alternately raised and lowered by the protrusion and withdrawal of a plunger working below the surface. Pressure-pumps for transmitting and storing power for hydraulic machinery, and oil-line pumps, also demand certain departures from the conventional forms to fit them for the requirements of their several duties.

1.—CRANK AND FLY-WHEEL PUMPS.

This type of pump results very directly from the desire to adapt the ordinary steam-engine for pumping purposes. The cross-head, connecting-rod, and crank of the typical engine are retained (or what may replace them), and the pumping-piston is secured to a direct or indirect prolongation of the steam-piston rod.

This form of pump has several advantages. The living force stored in the fly-wheel will carry the reciprocating parts past the centers, and therefore the ordinary slide-valve can be used on the steam-cylinder. Moreover, the valve can be driven positively by an eccentric on the rotating shaft. There will, therefore, be no danger at ordinary speeds of the "stalling" of the pump with the valve covering both steam-ports. The valve also is not liable to fail to operate because small steam-passages have become clogged by gummed lubricant. A second advantage is that the pump-stroke is of positive length. The throw of the crank determines the travel of the pistons, and hence there is no necessity for large percentages of clearance to prevent an overstroke from injuring the cylinder-heads. The whole length of the pump-barrel must be swept through at every stroke. This

avoids the losses of efficiency due to partial strokes which are occasionally made by pumps whose stroke is controlled by steam only. This type of pump can also be run very fast for the same reasons. A third advantage is that the fly-wheel and attachments serve as a reservoir for work imparted to them during the first half of a stroke which must be given out during the latter half. Hence the steam can be worked expansively in the cylinder, from which results a saving of fuel.

Moreover, by the use of the slide-valve controlled by an eccentric or crank, the steam is gradually admitted to the piston as the port-opening increases. By this means is avoided some of the shock of impact of steam upon the piston-head, and the pump reciprocates more quietly. Also, the simplicity of the valve-gear reduces the number of its parts, and renders it intelligible to a man of limited resources and reparable by him in case of injury.

Again, the less velocity of the water-piston at the beginning and at the end of a stroke permits the water-valves to seat themselves with less jar than when the piston starts from rest with its full velocity.

The disadvantages of the fly-wheel pump are—

First, that it cannot be made to run very slowly. There must be a sufficient number of strokes per minute to keep the rate of the fly-wheel from falling below a certain minimum, or else the pump will stall.

Secondly, the inertia of the fly-wheel will carry forward the reciprocating parts, and the water-column crashing through any obstruction which may have come in by the water-passages. Fracture of some part is very likely to result.

A third objection to this form of pump is the varying velocity imparted to the water column by the varying velocity of a piston whose motion is controlled by a uniformly-revolving crank. There will be irregularity of flow, and consequent strain upon the forcing-pipe as a result of this.

Moreover, the pump will not start itself from rest when "centered", or on the dead-points, or when the steam-valve covers both parts. The fly-wheel must be turned over by hand in this case, which makes it necessary that the pump be in an accessible place.

The valve for distributing steam to the two ends of the steam-cylinder is the plain flat slide-valve in nearly all cases. In one or two designs the valve is of the balanced type, to relieve the pressure upon the seat. Usually, however, the valve-area is small and balancing is thought unnecessary. When balanced, the valve is of the piston form. The valve-seat is put either upon the top or upon the side of the steam-cylinder in horizontal pumps. There are advantages in having the steam-chest upon the side, first, because the condensed water in the cylinder will escape naturally into the exhaust-passage through the ports, and, secondly, because the valve-rod enters the stuffing-box in the plane of the crank-shaft, so that no rock-shaft is required to transmit motion from the eccentric. The relief of condensation into the exhaust avoids the use of drip-cocks with either their multiple connections to drains or else their "sloppiness". One of the vertical pumps accomplishes the same purpose by using steam passages of unequal length (Fig. 28). The valve-stem is usually guided by the stuffing-box alone. In the pumps with short connections (Fig. 5) the eccentric-rod is usually cast as part of the strap, and connects with the valve-stem by a pin-joint. The strap is made wide and solid. Where rocker-arms are used, they are either levers of the third order, pivoted at one end (Fig. 14), moved by the eccentric in the middle, while the valve-rod is attached to the free end, or else they are levers of the first order, the eccentric-arm hanging down and the valve-arm pointing up (Fig. 18). In two cases the rock-shaft passes into the chest through a stuffing-box, and moves the valve inside by a finger (Figs. 16 and 22). There is but one case of a long guided valve-stem.

These fly-wheel pumps are made both horizontal and vertical. There are several types of arrangement of parts of the horizontal pump, of which Fig. 14 illustrates one design. The steam and water piston-rods are in the same

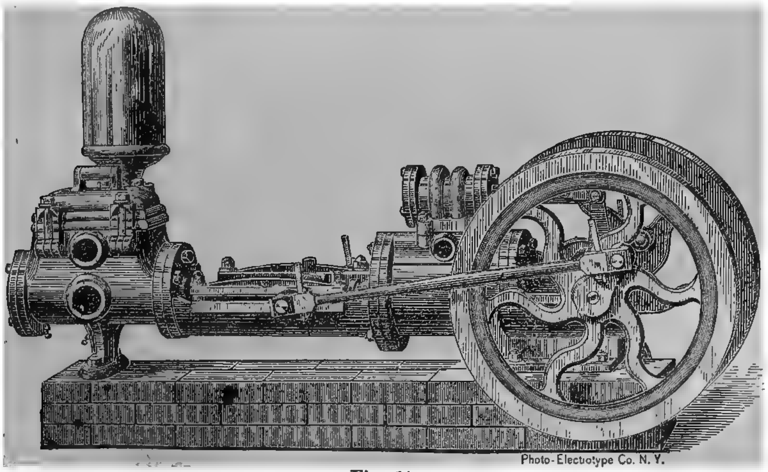

Fig. 14.

line, and are connected together by being keyed into a horizontal cross-head between the two cylinders. This cross-head slides between guides, and is quite long at right angles to the rods. The ends are turned to serve as cross-head pins for the ends of two connecting-rods. These latter connect to crank-pins upon the spokes of two

overhanging fly-wheels upon a shaft behind the steam-cylinder. The slide-valve is driven by an eccentric in the middle of the shaft, from which motion is carried to the valve-stem by a rocking arm pivoted below. The

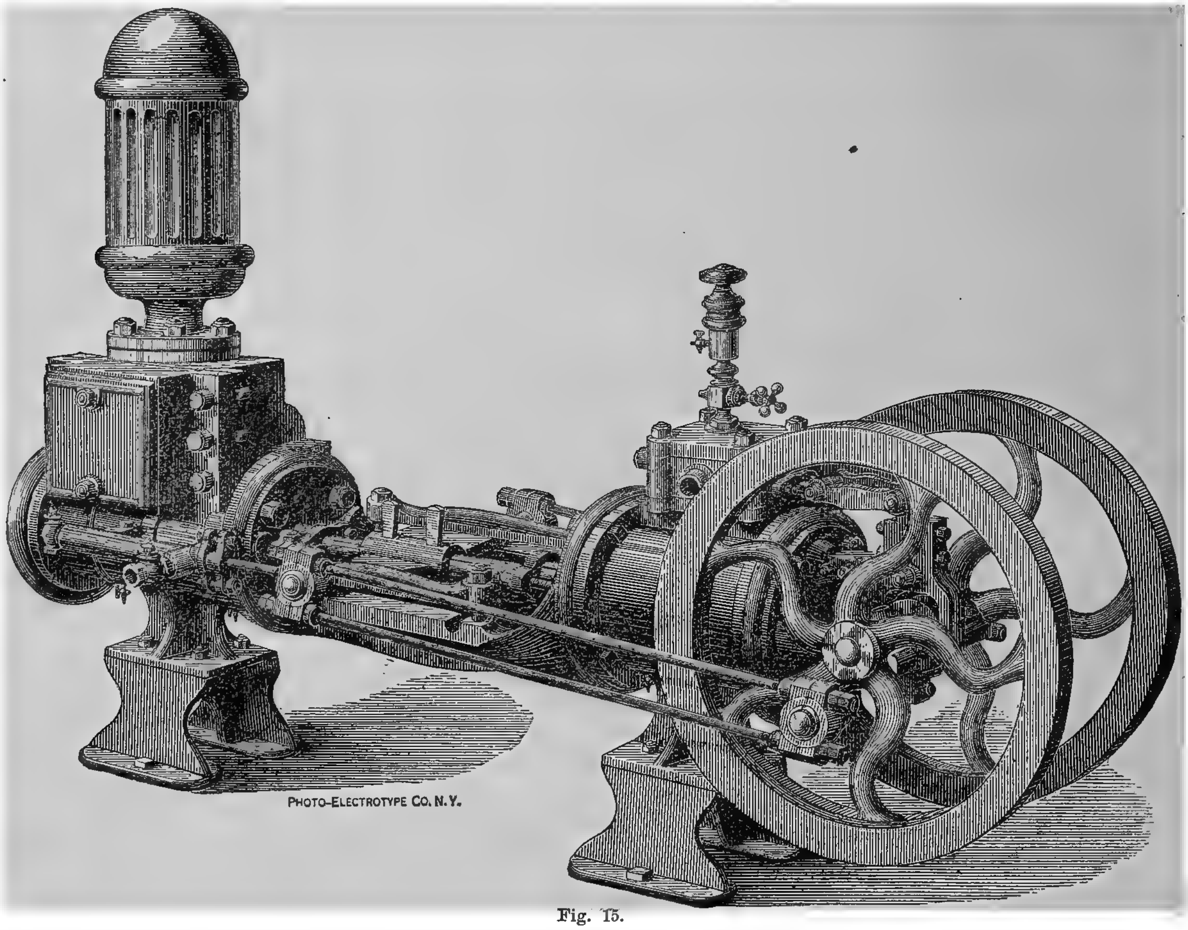

Fig. 15.

disadvantage of this arrangement is that access to the rear head of the steam-cylinder can only be had by taking that end of the pump apart. A similar design is shown by Fig. 15. The valve is worked by a yoke-motion.

Fig. 16 shows a modification of these designs.

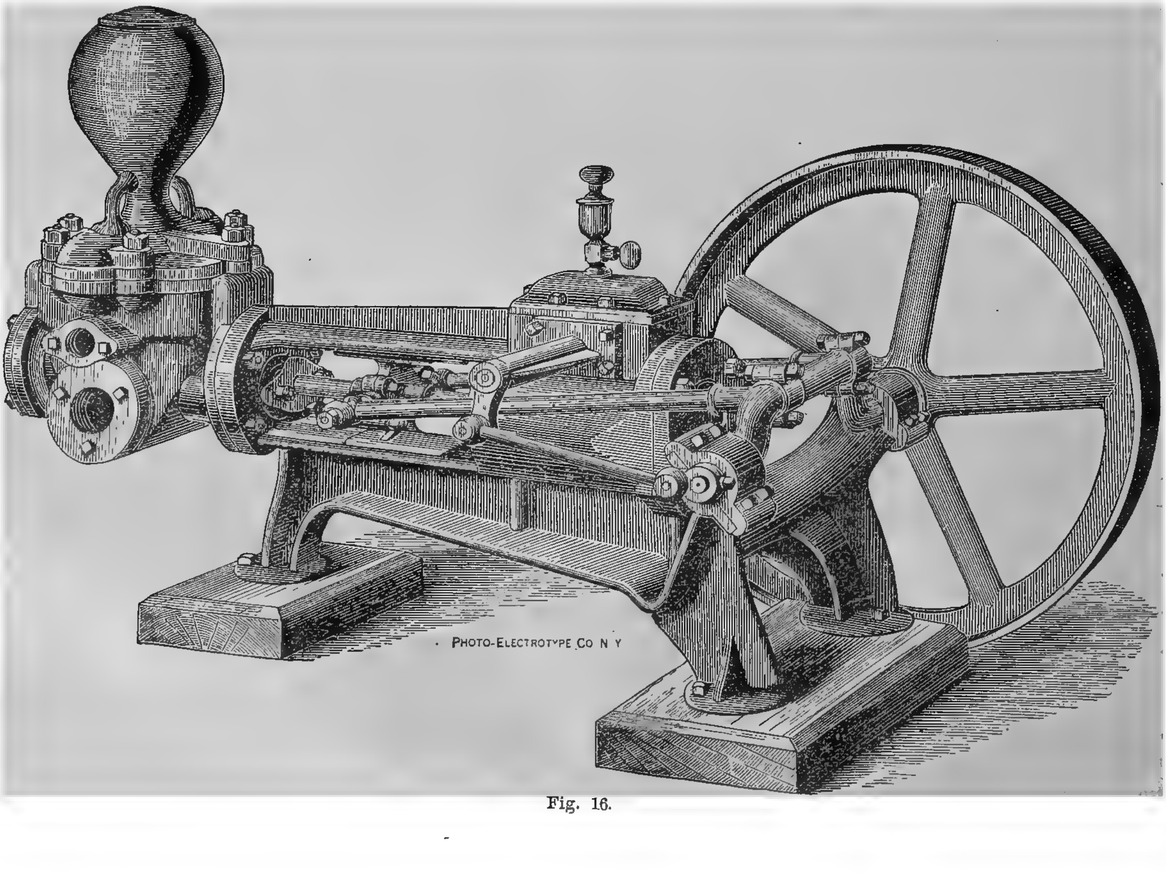

Fig. 16.

A second design is illustrated by Fig. 17. The two fly-wheels are keyed on a shaft which is carried upon the cradle between the two cylinders. The long cross-head is at the back of the steam-cylinder, driven by a

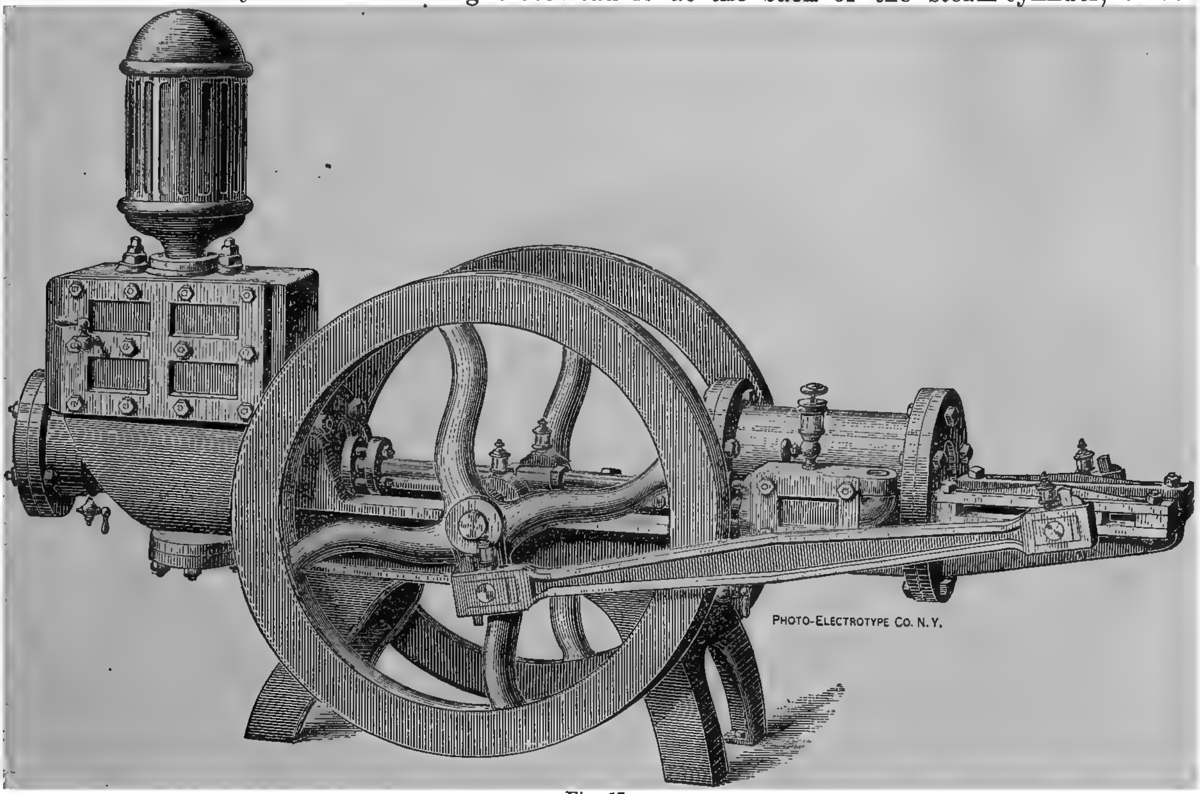

Fig. 17.

prolongation of the steam piston-rod through the back head. The same arrangement of outside connecting-rods is here used, and the slide-valve on the side of the steam-cylinder is driven directly from the eccentric. From the necessity of having the piston-rod cross the fly-wheel shaft, it will be seen that the dead-point of the cranks does

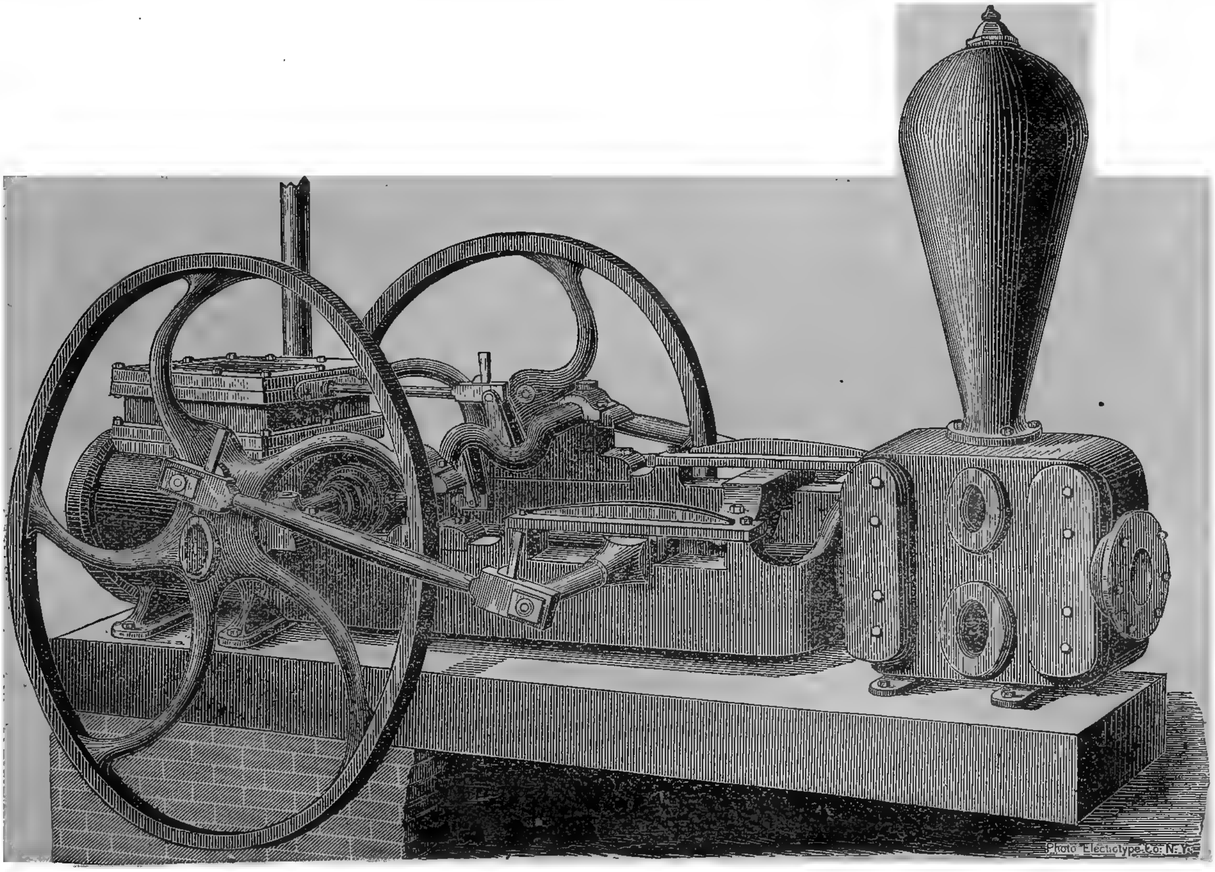

Fig. 18.

not coincide with the end of the piston-stroke, and consequently the danger of stalling is diminished at low speeds. This advantage is common to all pumps which have this feature.

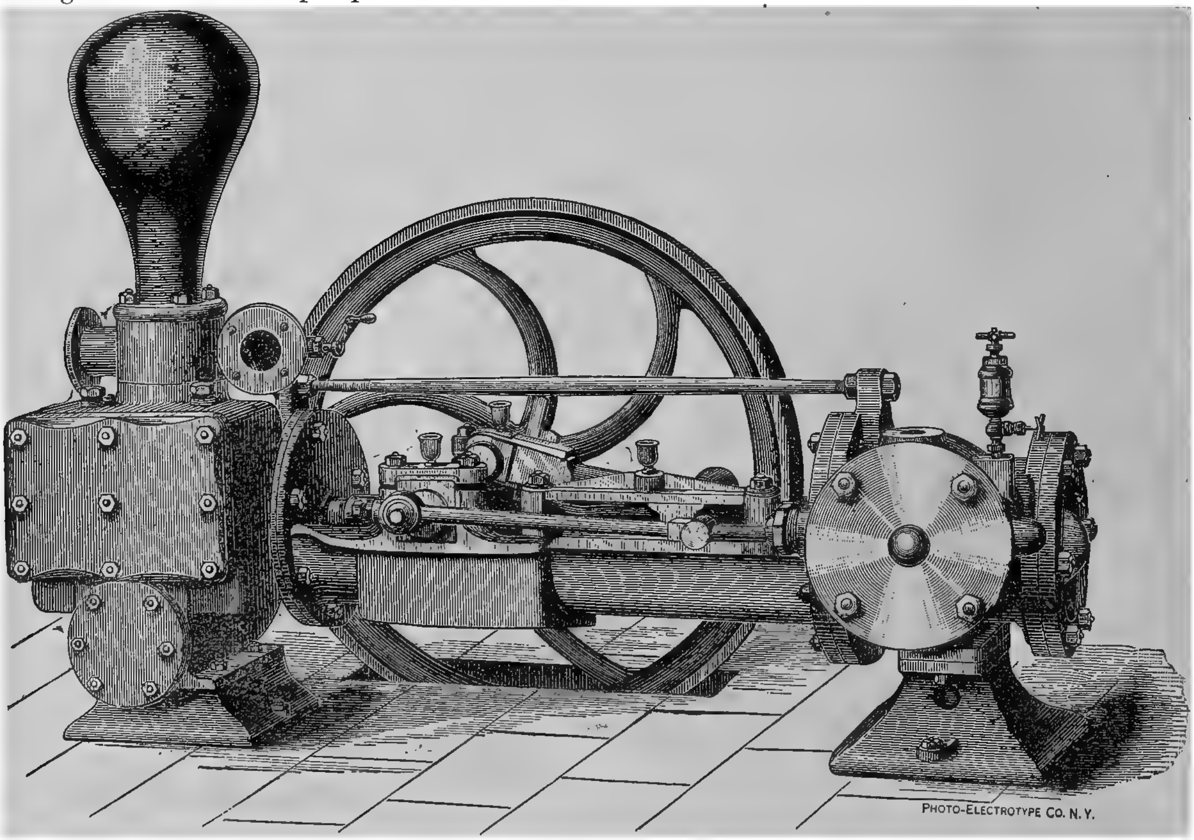

Fig. 19.

In the next type, shown in Fig. 18, both cross-head and fly-wheel shaft are between the cylinders. The

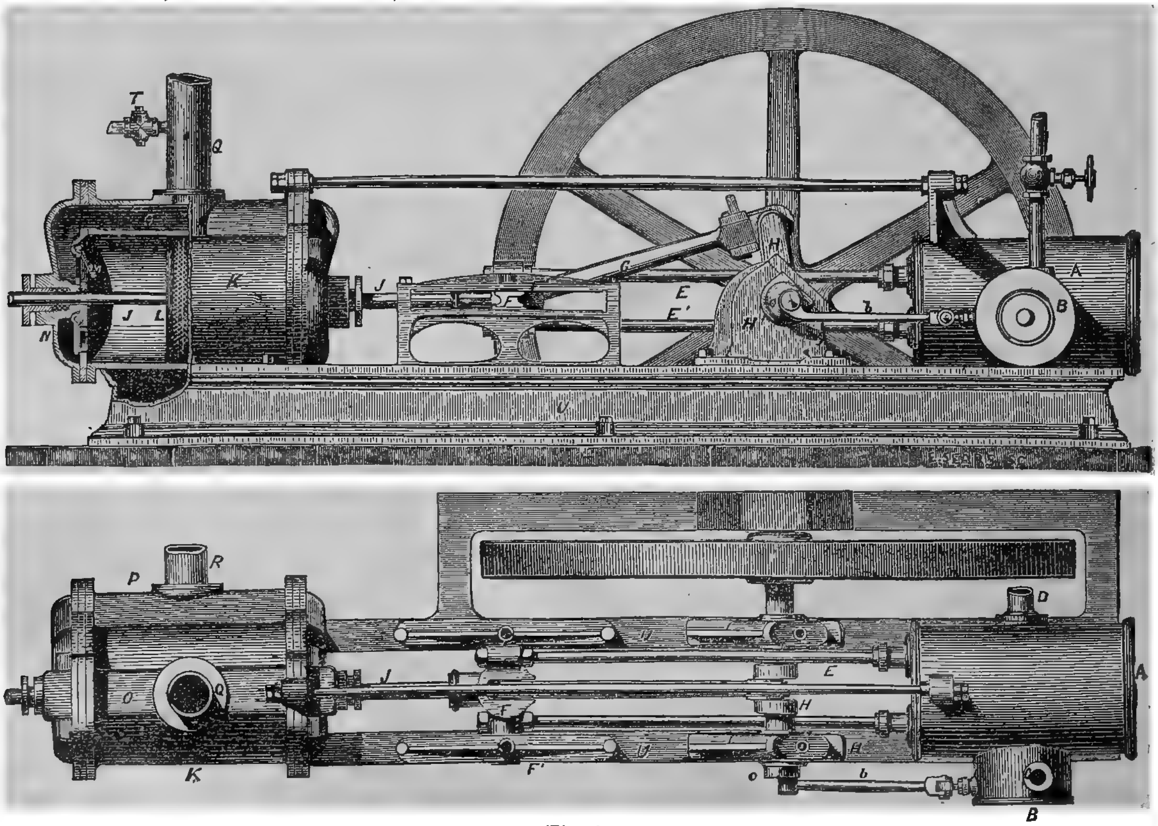

Fig. 20.

continuous piston-rod passes below the shaft, and the valve is driven through a rock-shaft and arms. This arrangement permits easy access to the cylinders.

A modification of this type, using only one fly-wheel, and with the mechanism inside the cradle, is shown in Fig. 19. The cross-head is guided upon one side only, the double crank revolving at the side of the piston-rod, which passes under the shaft. A short connecting-rod unites the crank to the cross-head, and the valve is driven from a crank-pin on the end of the fly-wheel shaft.

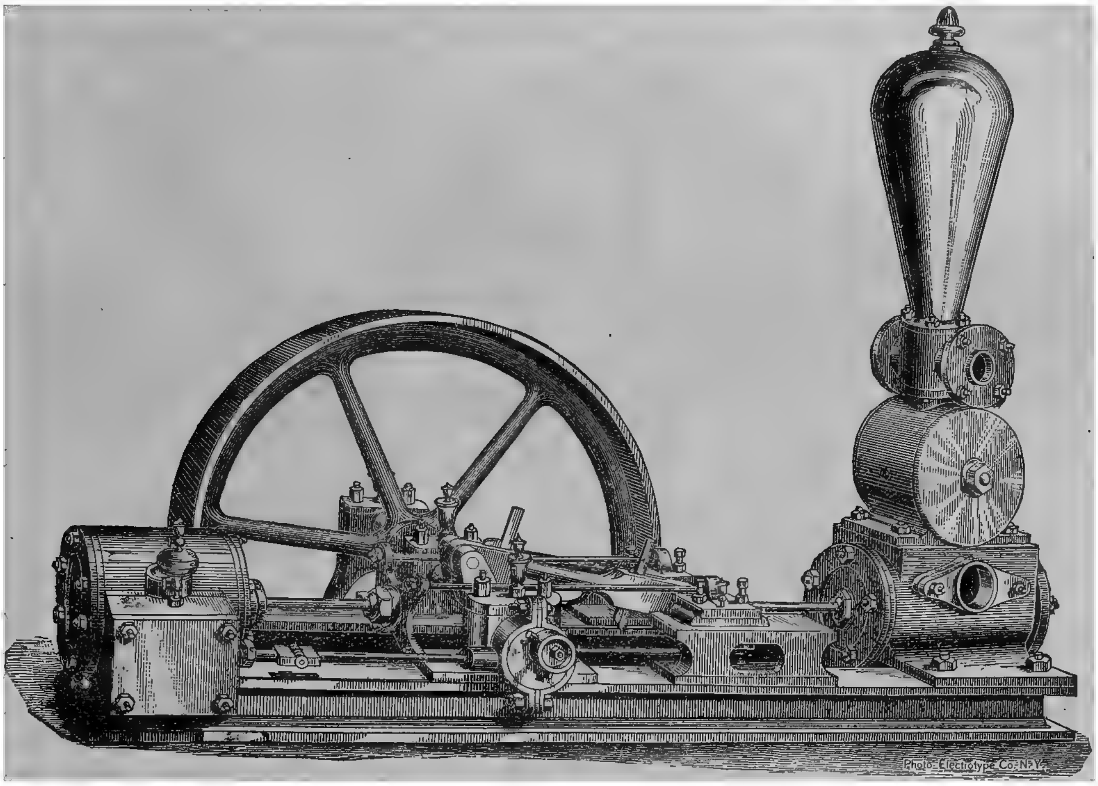

Fig. 21.

Fig. 20 shows a modification of this form, suggested by the engines for some screw-vessels. There are two steam piston-rods connected to the guided cross-head, one above and one below the center-line and far enough apart

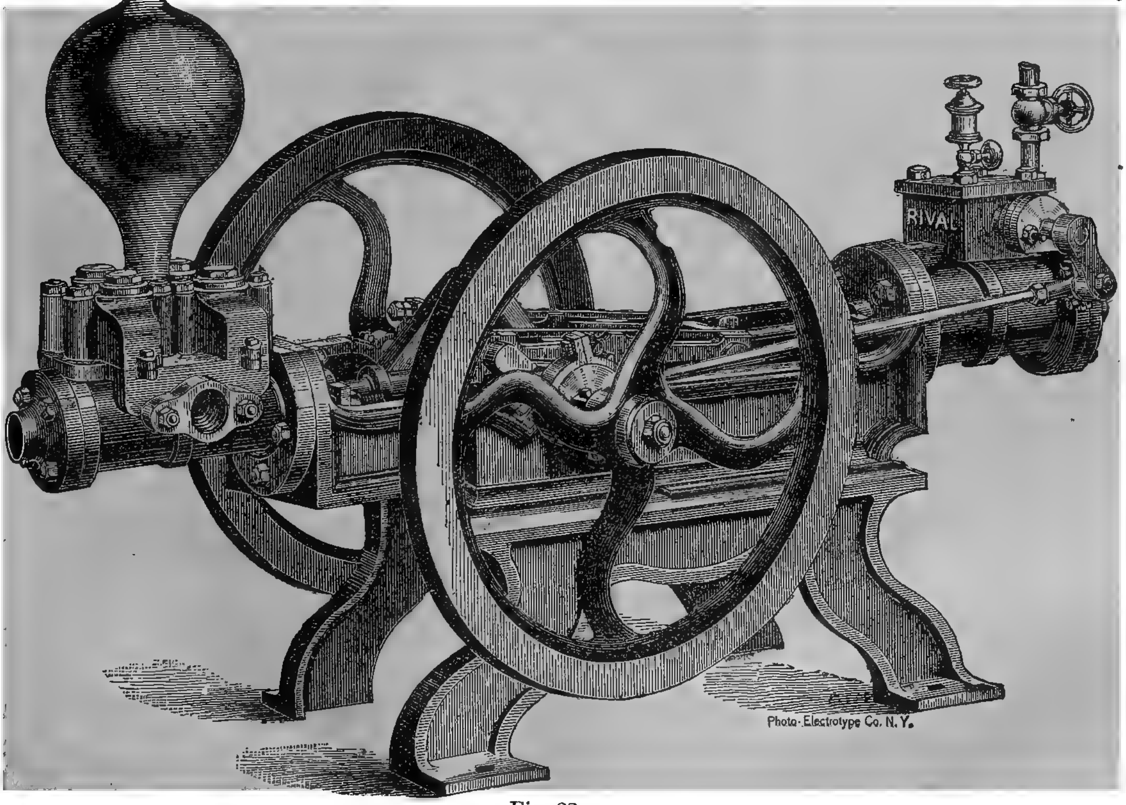

Fig. 22.

to permit the crank to revolve between them. The fly-wheel shaft has three bearings, and the valve is driven directly.

In the design shown in Fig. 21 the steam piston-rod bears a spider of four arms, which is connected to the guided cross-head by four long bolts or rods. This leaves an open space for the double crank and for the connecting-rod between the pairs of rods.

Another form is shown by Fig. 22. Here the cylinders are at the ends of the cradle, and the two piston-rods are keyed to the ends of an open forging, the crank-shaft traversing the opening. The forging is so shaped that

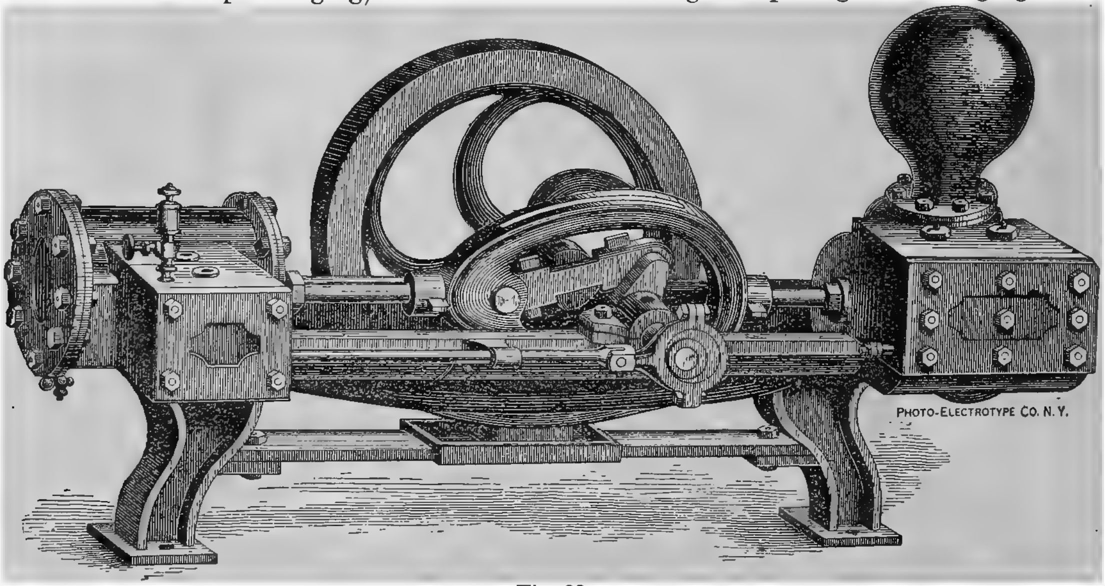

Fig. 23.

cranks on the shaft will clear its sides, these cranks being driven by two connecting-rods from a short guided cross-head keyed on the steam-rod. This arrangement permits a short bed-casting, the cylinders being bolted to the ends. A modification of this again is shown by Fig. 23, where the yoke is lengthened and receives an egg-shape for the opening. In a slot in the smaller end is pinned a short connecting-rod, which drives a crank revolving in

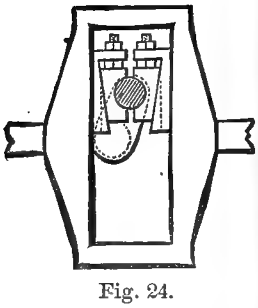

Fig. 24.

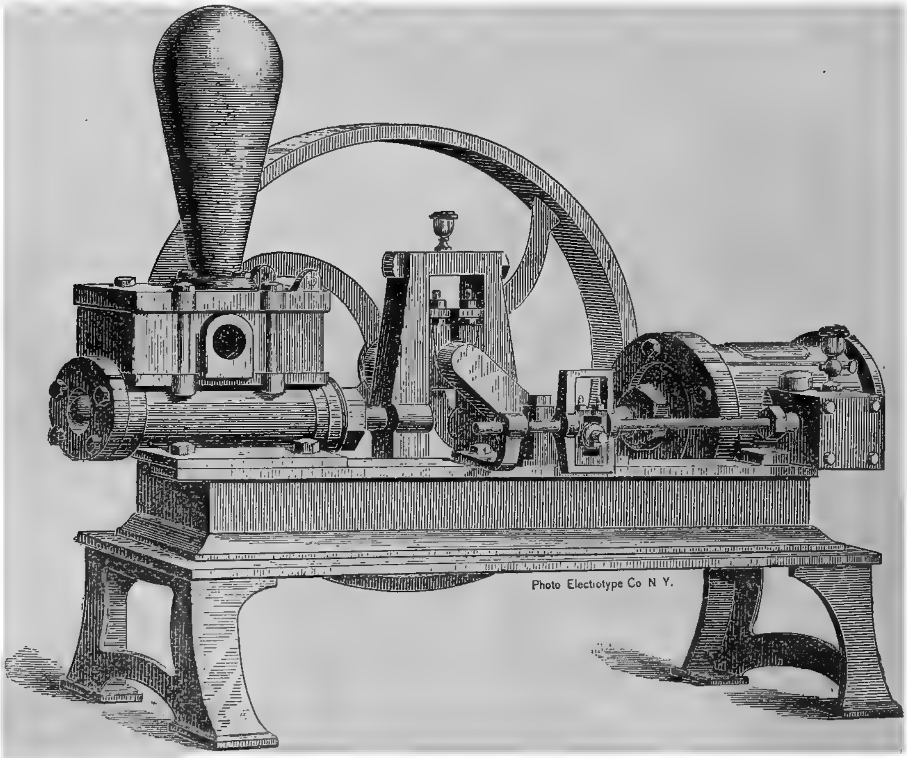

Fig. 25.

the opening of the yoke. The yoke is supported and guided by a slide below the cradle, an arrangement which permits easy and thorough lubrication.

In the remaining type of horizontal pump, which is preferred by several makers, the connecting-rod disappears. The reciprocating motion of the piston-rod is transformed to rotary motion for the fly-wheel shaft by the well-known device shown in Figs. 24, 25, and 26. The two rods are screwed or keyed to the two halves of a solid or

bolted yoke, between whose inner parallel faces slides a block, enveloping the pin of a double crank. The vertical components in the motion of the crank are taken up in the yoke, while the pistons appropriate only the horizontal

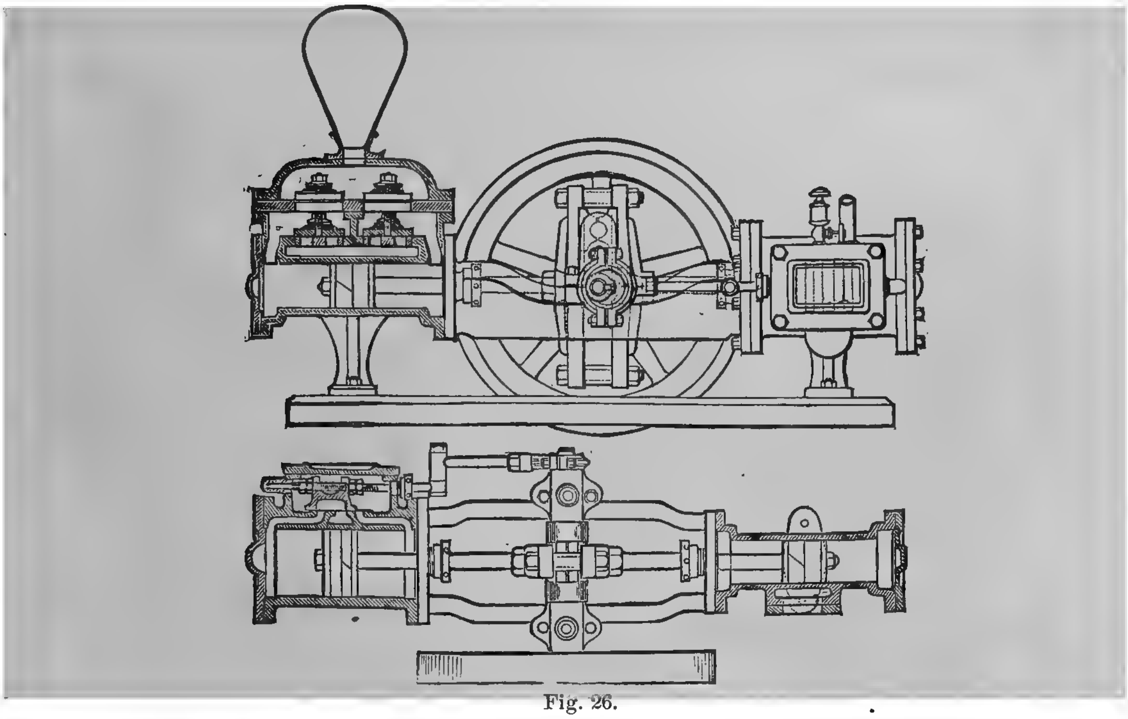

Fig. 26.

motion. Hence the pistons move as though controlled by a connecting-rod of infinite length. There would be a practical loss from friction if much power had to be given out at the crank, but as the only duty is to rotate the

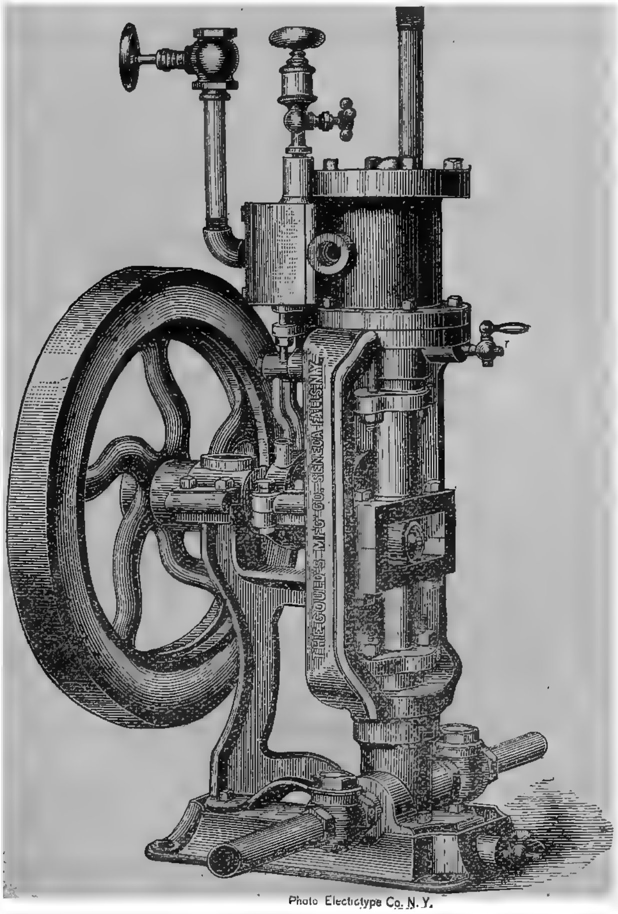

Fig. 27.

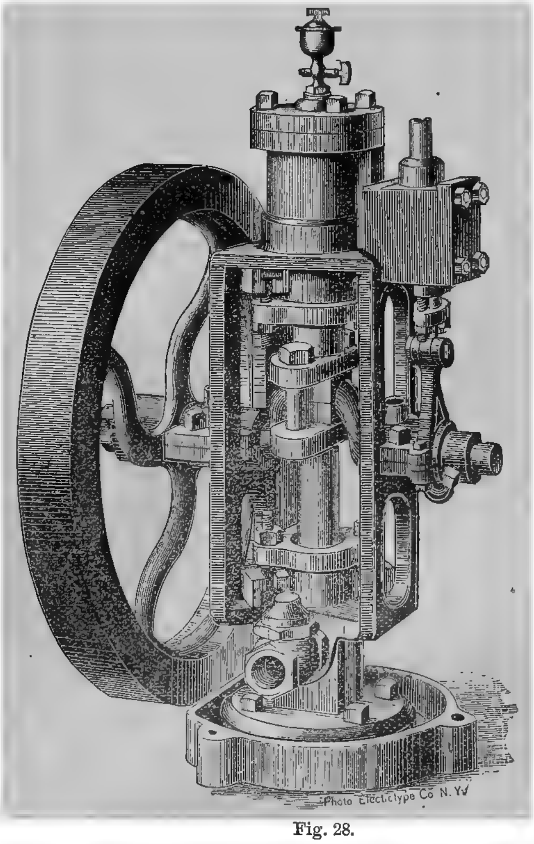

Fig. 28.

fly-wheel shaft, this is no obstacle. This arrangement permits wear to be taken up very easily, either by the jam-nuts upon the bolts (Fig. 26) which unite the yoke, or by tightening down the wedge-shaped faces of the slide-block (Fig. 24). The faces of the slide-block are babbitted, as also are the bearings of the two halves upon the crank-pin.

Several of these forms of pump are also made to work vertically for deep wells or similar purposes. The only difference made is in the length of the connections between the steam- and the water-cylinders. There are several, however, which are always made as vertical pumps, especially in the small sizes designed for boiler-feeders. These are illustrated by Figs. 27, 28, 29, and 30. The arrangement of the mechanisms is clearly shown in the cuts. Some

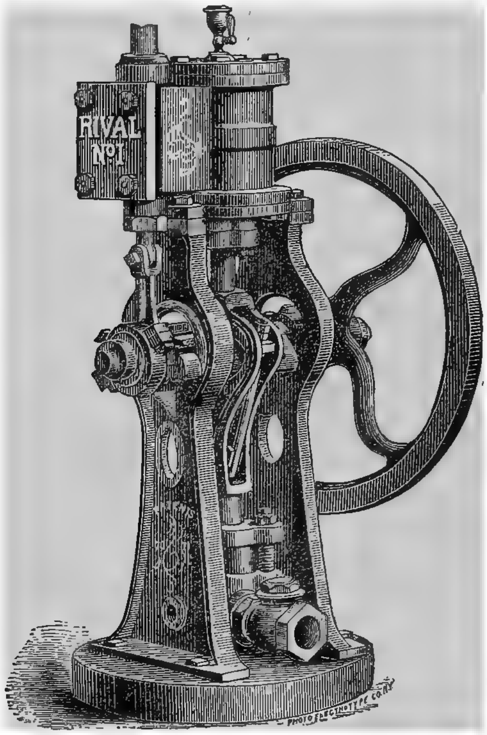

Fig. 29.

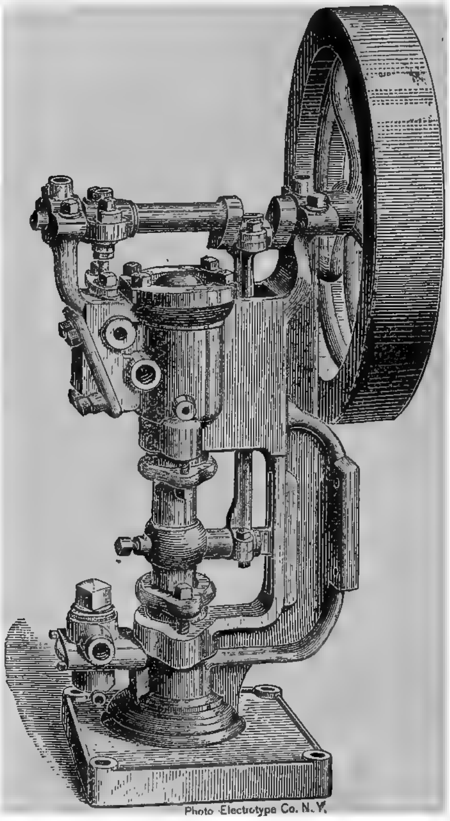

Fig. 30.

use the cross-head and connecting-rod, some the open yoke and connecting-rod, and others the bolted or solid parallel yoke with slide-box enveloping the pin of the crank.

In all these forms of pump where the piston is not continuous, the two ends will be secured to the yoke or cross-head in the best practice by keys. The ends of the rods and the sockets for them will be turned and bored tapering, and a key passing through both holds all securely. In a few cases, the rods are screwed into their sockets and are held from turning by jam-nuts. The method by keys is to be preferred, although not always the cheaper.

The fly-wheel pump as a type seems to be preferred at the West. It is also very largely used on shipboard and on river vessels. It has the advantage that it can be run as an engine by putting a belt on the fly-wheel, and can be very easily worked as a hand-pump in an emergency. It is, however, to the reliability claimed for it by those accustomed to its use, that its popularity is largely due.

2.—DIRECT-ACTING PUMPS.

The term "direct-acting" is applied to those pumps where the two pistons are on the same rod and there is no rotary motion in the mechanism. The crank-shaft, fly-wheel, connecting-rod, and crank are all dispensed with, and the valve which distributes steam to the ends of the cylinder is moved by steam into the proper position, instead of being actuated positively from a shaft. In the design of pumps of this class two problems must be solved. It is necessary first to provide for the control of the length of the piston stroke. As there is no crank to limit its travel, there is danger at high speeds lest the piston strike the cylinder-heads, and at low speeds lest only a partial stroke be made. The former is, of course, the danger most to be dreaded, and it is avoided in two ways. The steam passages may be so arranged that the exhaust-port shall be closed before the stroke is entirely completed (Fig. 45), and thus the piston shall be arrested by a cushion of steam inclosed in the cylinder. The other way is to give lead to the distributing-valve, so that boiler-steam reaches the piston before it has reached the cylinder-cover. In either case more clearance is judicious than is necessary in the other type.

The other problem to be solved is the moving of the steam-valve where there is no momentum of a fly-wheel to carry it past its central position when it covers both ports. It would seem as though the pump must stop after

every stroke. The general solution of this problem is found in the employment of a second small steam-cylinder and piston whose function is to move the valve for the large cylinder. It is in effect a second engine, to which the admission of steam shall be controlled or effected by the motion of the main piston. This small piston will be called the auxiliary or valve-piston, and the valve admitting steam to this small cylinder will be called the auxiliary valve. A complete typical cycle would therefore consist first of the admission of steam to the auxiliary piston, the opening of the main steam-port by the main valve moved by this auxiliary piston, the stroke of the main piston, the movement of the auxiliary valve by the main piston, the motion of the auxiliary piston in the opposite way, and so the cycle would repeat itself for the return stroke.

The advantages of this form of pump are: First, that it can be run at very low speeds. Secondly, having no dead centers, there is no danger of the pump "stalling". For the same reason the pump must always start when steam is turned on, no matter how inaccessible or distant it may be. Thirdly, the essential parts are protected from injury by being to a greater or less extent internal. Some pumps show no mechanism at all on the outside, and in any case the pump is very compact and self-contained. Fourthly, many of the disadvantages of the fly-wheel pump are avoided, such as the varying velocity of the forcing column, and the sometimes inconvenient inertia of the fly-wheel.

On the other hand this type of pump has some disadvantages. The shock of the water-valves when the pump reverses promptly at speed, often prevents smooth working. This form sometimes makes only partial strokes. Expansion is impossible, except to a very limited degree. Not infrequently in some types the valve fails to throw over on the first stroke, and the pump will not start. This is usually due either to some defective expansion by heat, or else the small passages have been stopped up by a gummy lubricant or by scale or some similar cause. And finally, an appearance of complication due to the compactness and the number of small parts in the valve-gear, makes repair sometimes difficult from imperfect comprehension and poor facilities.

The differences in the various styles of direct-acting pump are mostly found in the valve arrangement. While all must use the auxiliary valve and piston, yet the different ways of utilizing them give rise to several varieties. The auxiliary piston is nearly always double-headed. In form it is not unlike a piston-valve. The larger sizes have spring packing-rings; the smaller ones are solid. The slide-valve which it is to move, either fits between grooves in the smaller central part of it, or else has a vertical lug which fits into a cavity left in the open middle part. Usually the steam is at all times upon the central part and acts equally upon the two heads. The piston is moved either by admitting live steam to one outer head while the other is in communication with the exhaust, or else by opening one outer head to the exhaust with previous equilibrium of pressures. In either case the piston moves in the direction of least resistance and carries the main valve with it.

This disturbance of the equilibrium of the auxiliary piston may be effected by a plain slide-valve, or the functions of this valve may be performed by some other part of the mechanism, and the slide-valve may disappear. In any case the admission of steam to the auxiliary cylinder must be controlled from the motion of the main piston. This may be effected directly from the piston inside the cylinder, or from an arm attached to the piston-rod outside. In the first type what are known as "short-connected" pumps can be used. The steam- and water-cylinders need be only far enough apart to permit the packing of the stuffing-boxes. This has the disadvantage of causing a part of the piston-rod to enter both hot and cold cylinders. Where the other system of an arm on the rod is used, the cylinders must be distant an amount equal to the stroke, in addition to the length of the clamp of the arm. These are called "long-connected" pumps.

There are several forms of direct-acting pumps where the essential parts are all present, with but little modification of the typical forms and of the underlying principle. Such a one is shown in Fig. 31. The main piston-rod carries a vertical arm which strikes tappets upon a rod which enters the valve-chest. These tappets are so placed as to be moved just before the piston completes its stroke. This tappet-rod has an arm inside the valve-chest, projecting from it at right angles and rectangular in cross-section. This arm rests between two ridges upon the back of a small slide-valve, whose motion must therefore be the same as that of the tappet-rod. The seat of this valve is in the spandrel between the main cylinder and the cylinder for the auxiliary piston. Its three ports communicate respectively with the two ends of the auxiliary piston-cylinder and with the exhaust of the pump, but there is also a passage to the ends of the auxiliary cylinder for exhaust only. This has only one-half the area of the similar steam-passage and enters the bore of the auxiliary cylinder nearer the middle. When the tappet-rod moves this auxiliary valve to one side, steam from the boiler is admitted through one port to the end of the auxiliary cylinder. The space at the other end is by the same motion opened to the exhaust through the hollow in the face of the slide-valve, and the piston obeys the excess of pressure and moves in the direction of its axis. This motion compels the motion of the slide-valve controlling the admission of steam to the main cylinder, because the main valve fits into this auxiliary piston at the reduced section of the middle, so that they must move together. Steam from the boiler, therefore, meets the main piston at or just before the completion of its stroke, and the cycle is repeated. The chest-piston is cushioned from going too far by its own exhaust steam, since in its motion toward the head of its cylinder it closes over its own exhaust-opening and shuts in a part of the steam which drove it on the preceding stroke. In this form of pump, therefore, the two engines with their two slide-valves are

clearly present. One engine has for its sole function the moving of the slide-valve for the other and larger one, while the large engine moves the slide-valve for the smaller. To guard against the possible accident at high speeds that the auxiliary piston should not move the slide-valve soon enough to insure steam-lead on the main piston, the

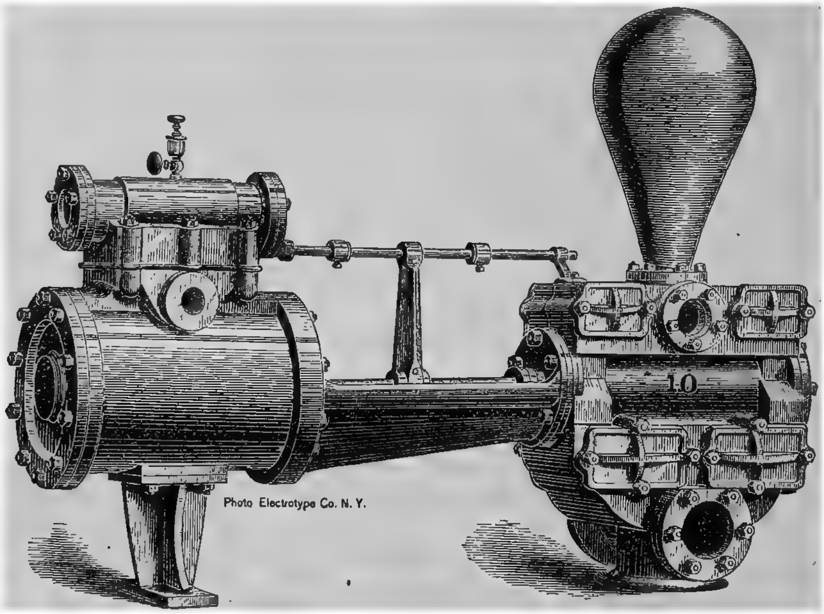

Fig. 31.

internal arm on the tappet-rod which moves the auxiliary valve rests between projecting ridges or lugs on the back of the main valve. These lugs are just so far apart that ordinarily they will not be touched by the arm as the main valve moves away from before it. Should the main valve fail to move, however, in time, this tappet-arm is moved forward against the lug by the advance of the main piston and will compel the motion of the main valve.

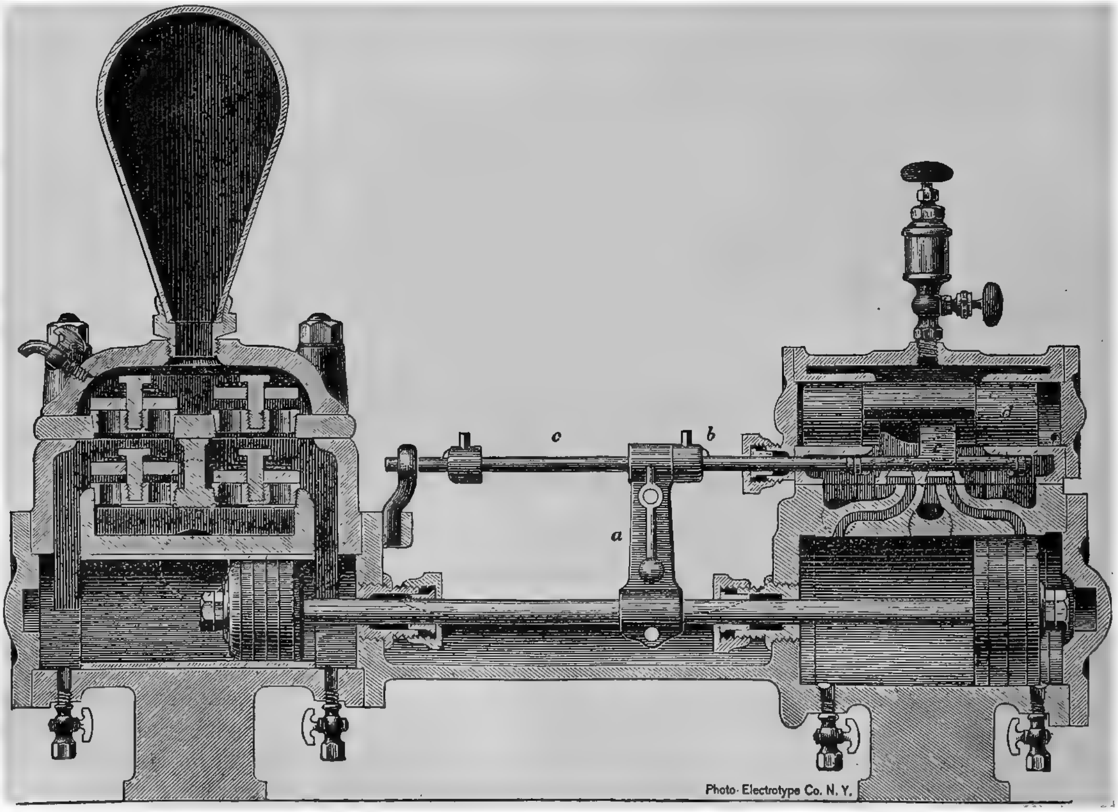

Fig. 32.

Steam-lead will thus be given before the main piston has struck the cylinder covers, even though the auxiliary piston had failed to act.

A similar type is illustrated by the pump shown in Fig. 32. The auxiliary valve is moved in the same way, by an arm on the main piston-rod which strikes tappets or chocks on the valve-stem. The valve is a flat slide-valve

surrounding the main valve and sliding upon the same faced surface. There are two ports upon each side of the auxiliary valve and covered by it, communicating with the spaces at the end of the auxiliary cylinder. One is for steam to each end on one side, and those on the other are for exhaust. At the proper time when one steam-port is uncovered by the valve, the exhaust-hollow is in communication with the exhaust-passage from the other end of the auxiliary piston, and the main valve is thrown over. The exhaust-passages are shorter than the steam-passages, and hence the auxiliary piston cushions itself after it has covered the opening of the exhaust-passage. There is a similar precaution in this pump to insure steam-lead on the main valve and to avoid overstrokes. A lug upon the valve-rod projects into a cavity upon the auxiliary piston. The length of this cavity is such that the piston and main valve will be moved bodily by the motion of the chocks on the tappet-rod, if steam has not carried them previously forward. The cylinder of the auxiliary piston in this pump is carefully jacketed by steam from the boiler, in order to avoid any difficulties from unequal expansion in first starting up. Where this precaution is not taken, there is danger lest the piston stick in the bore, when they are of different temperatures, and have been fitted to each other at the same temperature.

In pumps of this class, where the auxiliary valve is moved by the main piston, and steam is admitted to the ends of the auxiliary piston, it will be seen that the ordinary slide-valve or D-valve will not answer for the main valve. In the ordinary valve, the steam is admitted and cut off by the extreme edges, and the valve moves just

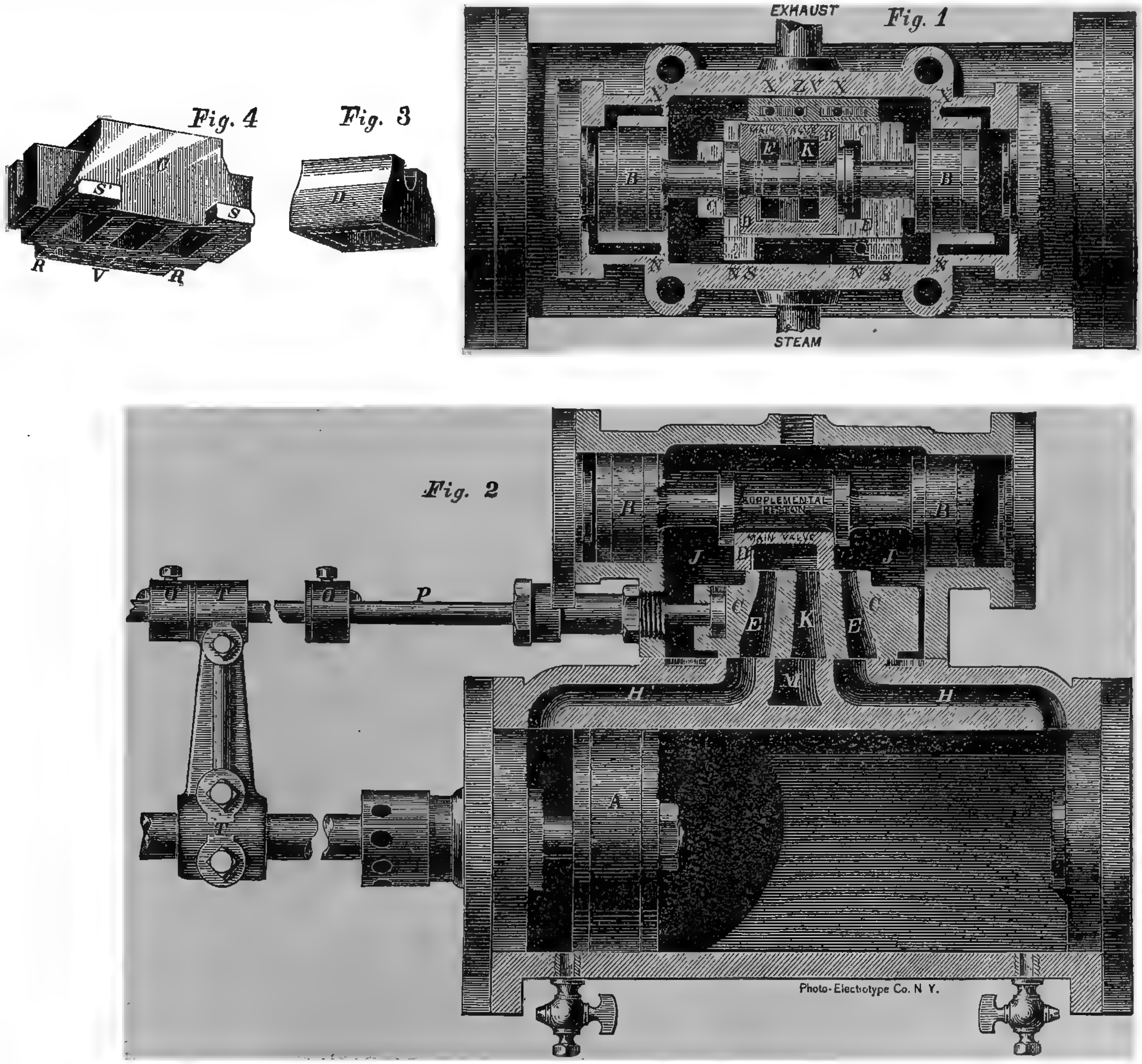

Fig. 33.

previous to admitting steam in the direction in which the piston is to be driven. When the auxiliary valve is of the D-form, and its steam-passages do not cross each other, it will be seen that the main valve will move in the direction just opposite to the future motion of the piston. Hence, especially in pumps which have the safety motion for the main valve, a form of valve must be used which shall be the reverse of the D-form, for either the auxiliary or the main valve. It must cut off and admit by its inner edges. This form of valve is shown in many of the sections, and is called from its shape the B-valve. Steam enters the port through one hollow in its face,

while the exhaust is taking place through the other hollow. The partition separates the live steam from the exhaust. Hence it is rendered possible for a piston, moving in one direction, to actuate a valve which shall admit steam properly to drive the piston in the opposite direction.

In the pump shown in Fig. 33 the auxiliary valve lies between the main valve and its seat. This movable seat is moved when chocks upon a rod are struck by a tappet-arm clamped to the main piston-rod. This seat has through ports, matching the ports in the lower face, and upon one side are projecting lugs which are faced to a joint with the lower seat. These alternately open and close connections to the spaces at the heads of the auxiliary cylinder. Similar projections on the other side carry exhaust-hollows for properly opening these spaces to the exhaust of the pump through a second pair of passages in the walls of the casting. It will be at once seen that the main valve of the D-form will be thrown by steam when the movable seat and auxiliary valve admits steam to one end of the auxiliary piston and connects the other end to the exhaust. The motion of the auxiliary piston is cushioned as before by its own exhaust, inasmuch as it covers over the exhaust-outlet before it has completed its travel. The exhaust-passages are shorter than those carrying live steam.

The main piston is cushioned by steam-lead. The safety device in this pump to avoid overstrokes is attained by the movable seat. There is no lap on the main valve, and in case of rapid strokes the movable seat will move sufficiently to admit steam directly without causing the auxiliary piston to move the main valve at all.

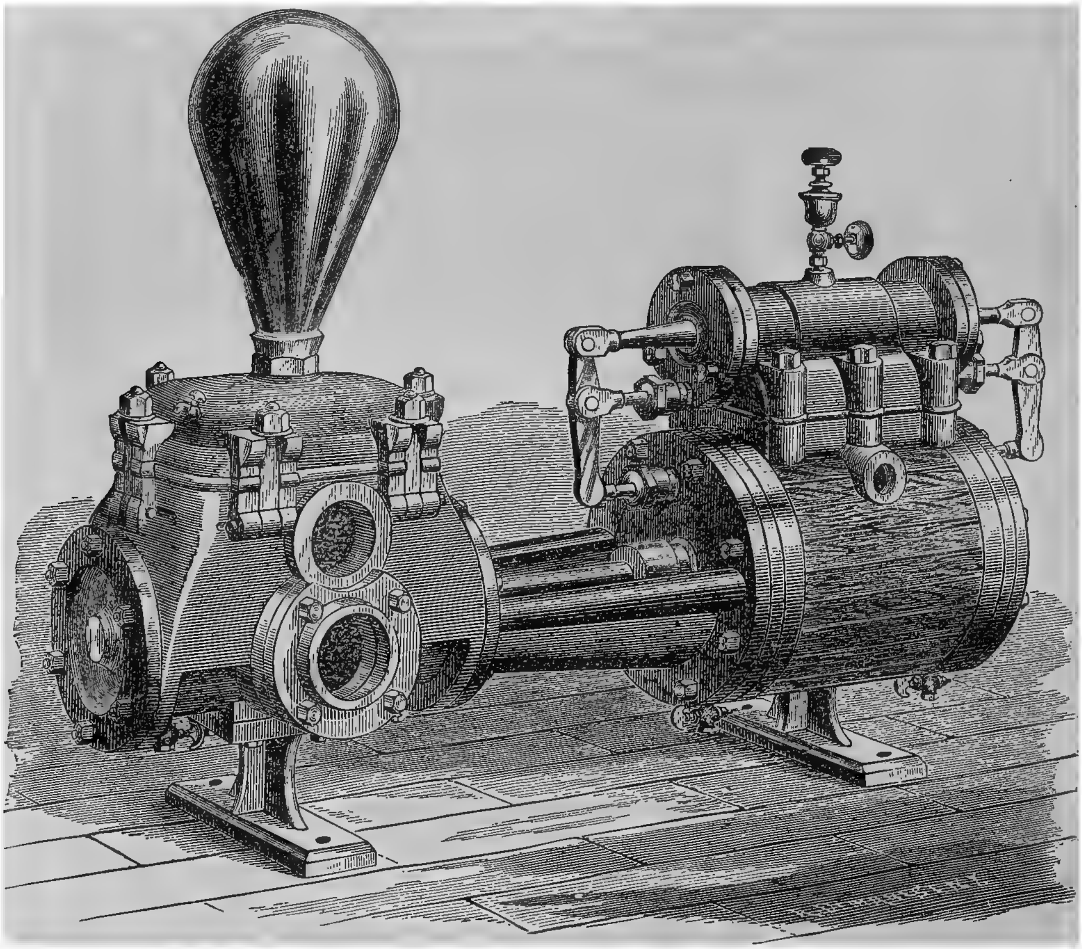

Fig. 34.

Where desirable to have a short connected pump of this design, the auxiliary valve is operated by the piston. Two short rods enter the cylinder-heads just above the center through stuffing-boxes (Fig. 34). These are struck by the piston just before completing its stroke in each direction. The motion of these rods is conveyed into the valve-chest by levers of the second order, whose fulcrum is a stud in the center of each end of the auxiliary cylinder. The seat is connected to the levers by links at about their middle point. The objections to this arrangement are the wear of the vibrating joints, and the necessity for extra stuffing-boxes. A plan tried at one time of having the seat moved by a rod struck alternately by steam- and water-pistons had to be abandoned because the rod would sometimes be moved by differences of fluid pressure upon its two ends.

A pump made in Pittsburgh, Pennsylvania, avoids the vibrating joints by using a larger rod to the seat, and making the connections to the rods entering the cylinder by rigid corners. When the piston strikes the short rod the whole frame moves bodily, shifting the auxiliary valve.

The pump shown in Fig. 35 moves the auxiliary valve by a pendant finger inside the valve-chest. The rocker-arm is moved by the horizontal rod, which receives its motion from the main piston through the two heads of the

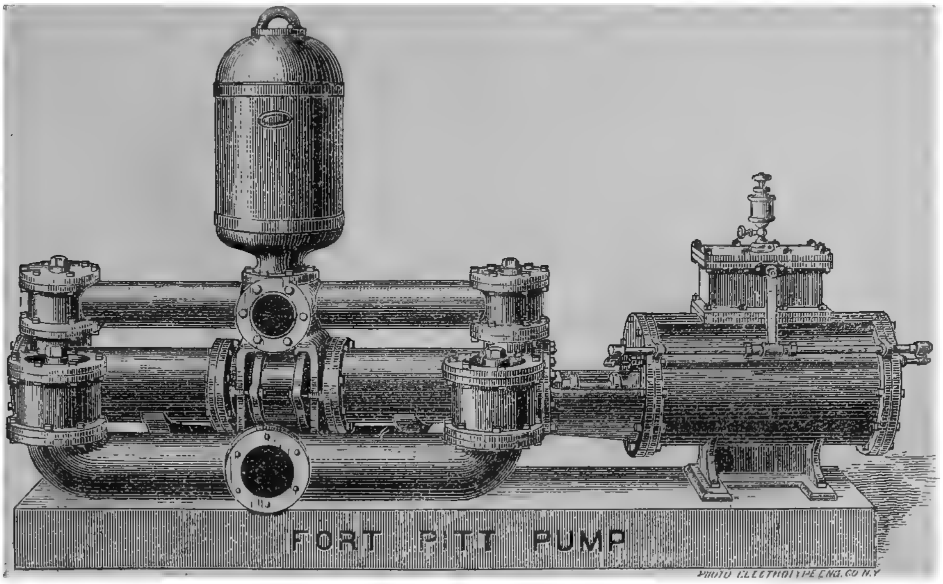

Fig. 35.

cylinder. The connection to the rocker-arm is made by a rounded contact-joint, so that here again the wear of a vibrating link is avoided.

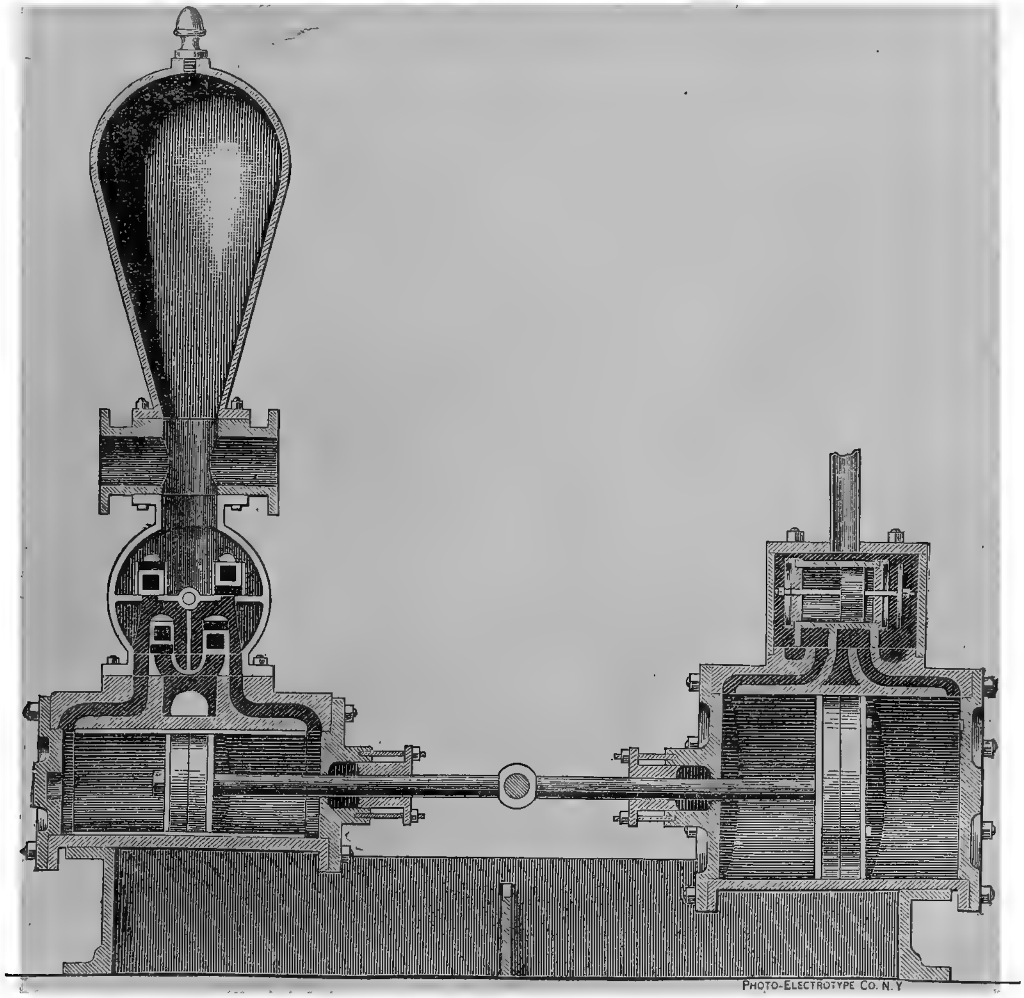

Fig. 36.

There are several inconveniences which are inseparable from the lack of positive connection between the main piston and the auxiliary valve. Such are the shock when the arm strikes tappets, and the danger of partial strokes. To avoid these is the object of several designs in which the arm clamped to the main piston-rod projects laterally

from it. A link carries the motion of this arm to a rocker-arm hanging vertically from a short shaft which enters the valve-chest through a stuffing-box. Inside the chest is a finger upon this shaft which slides the auxiliary valve when a slight rotation is given to the shaft from its connections outside.

A pump of this type is shown in Fig. 36. The flat auxiliary slide-valve is moved by the finger between the lugs upon its back. It is of the B-form and admits steam to the alternate sides of a piston which is stationary

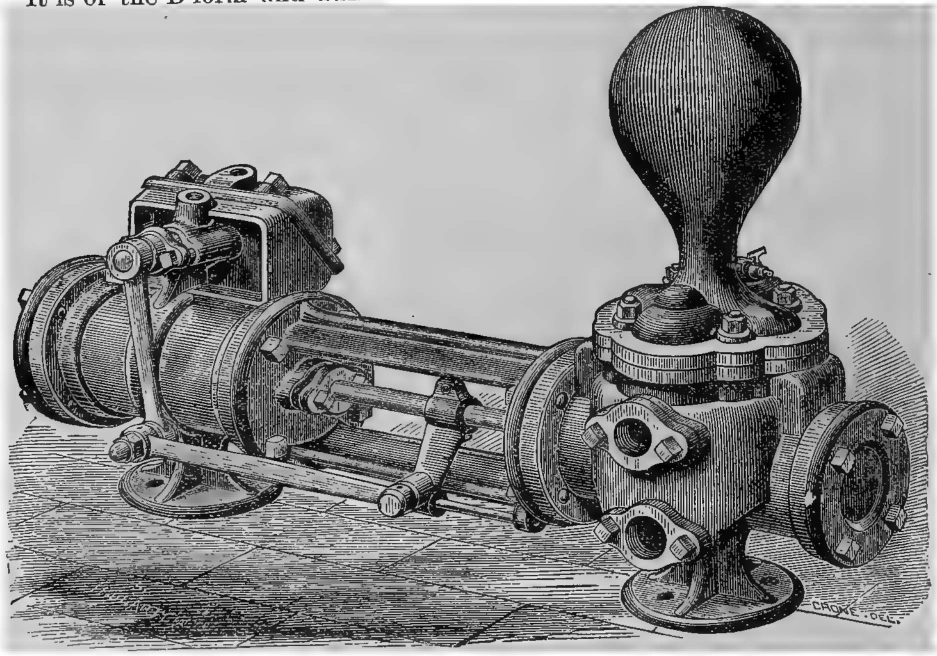

Fig. 37.

in a movable cylinder, of which the main valve is a part. The cylinder obeying the unbalanced pressure upon one of its heads, slides upon the seat and admits steam to the main cylinder. To cushion the motion of this valve-

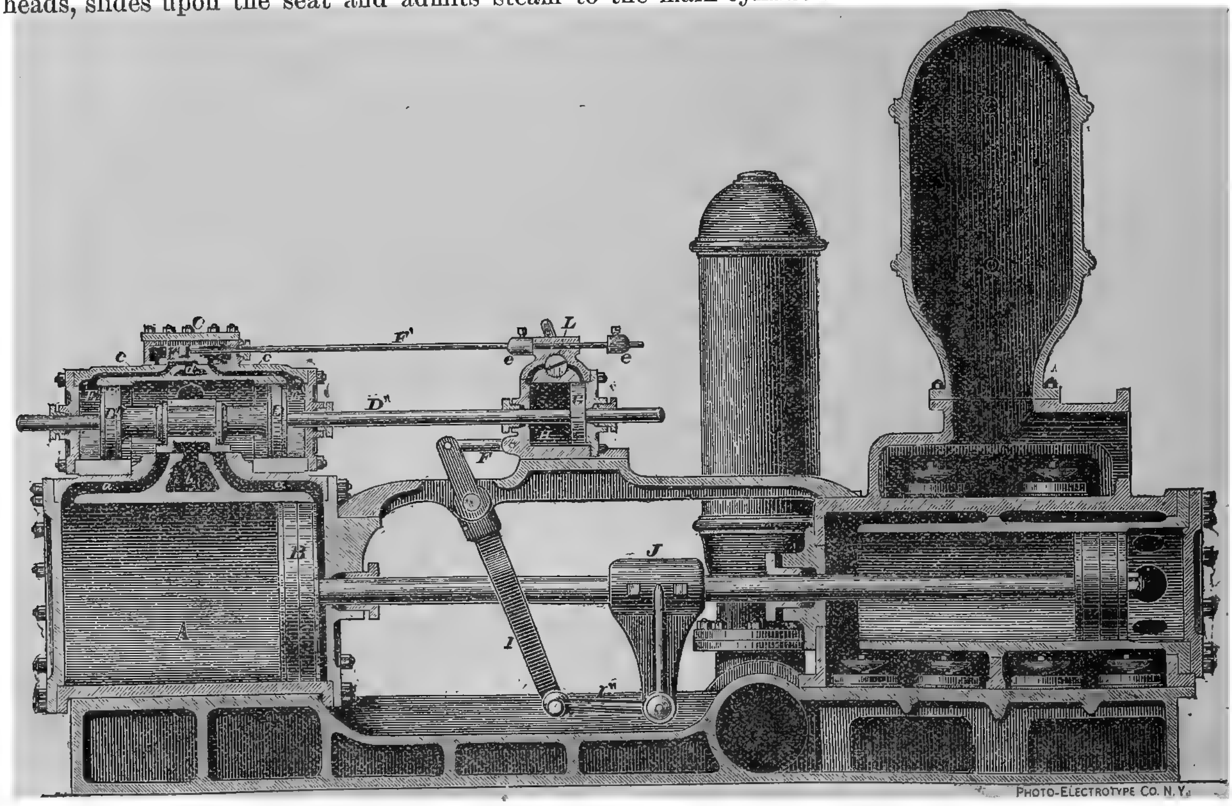

Fig. 38.

cylinder, the outer faces of its heads are bored out to fit two other stationary pistons upon the same rod as the internal one. These hollow faces compress the steam shut in when the cylinder caps over the pistons and thus arrest its motion. The main piston must have steam-lead.

Fig. 37 illustrates a pump using the more ordinary arrangement for operating the main valve, and admitting and

exhausting gradually from the piston. A notable feature of this design is the form of valve-chest. A very large opening is permitted by the use of the inclined joint for fitting and repair. The same builders have applied the principle of the Cornish cataract to their larger pumps, to compel a uniform speed of delivery. The arrangement is shown in Fig. 38. On top of the auxiliary cylinder is a small slide-valve, F, admitting steam to the auxiliary piston D. This valve is moved by collars *e* on its rod which are struck by a tappet-arm. The tappet-arm is on the top of a small cylinder, H, which slides upon guides as it is compelled by its connection to the main piston-rod through links to a swinging lever, I, from a clamped arm, J. The piston G which moves in this sliding cylinder is connected by a rod, D″, with the auxiliary piston and main slide-valve. It is this sliding cylinder which constitutes the cataract. It is filled with oil, and the two ends are connected together by an external passage, controllable by a valve, L. By this valve the time required for the oil to pass from one end of the cylinder to the other may be made greater or less. It will be at once seen that when the auxiliary pistons receive steam from the slide-valve, their rapid motion is impeded by the resistance to the displacement of the oil in the cataract, and the main piston therefore receives its steam slowly, and the water-valves may therefore seat themselves quietly. During the stroke

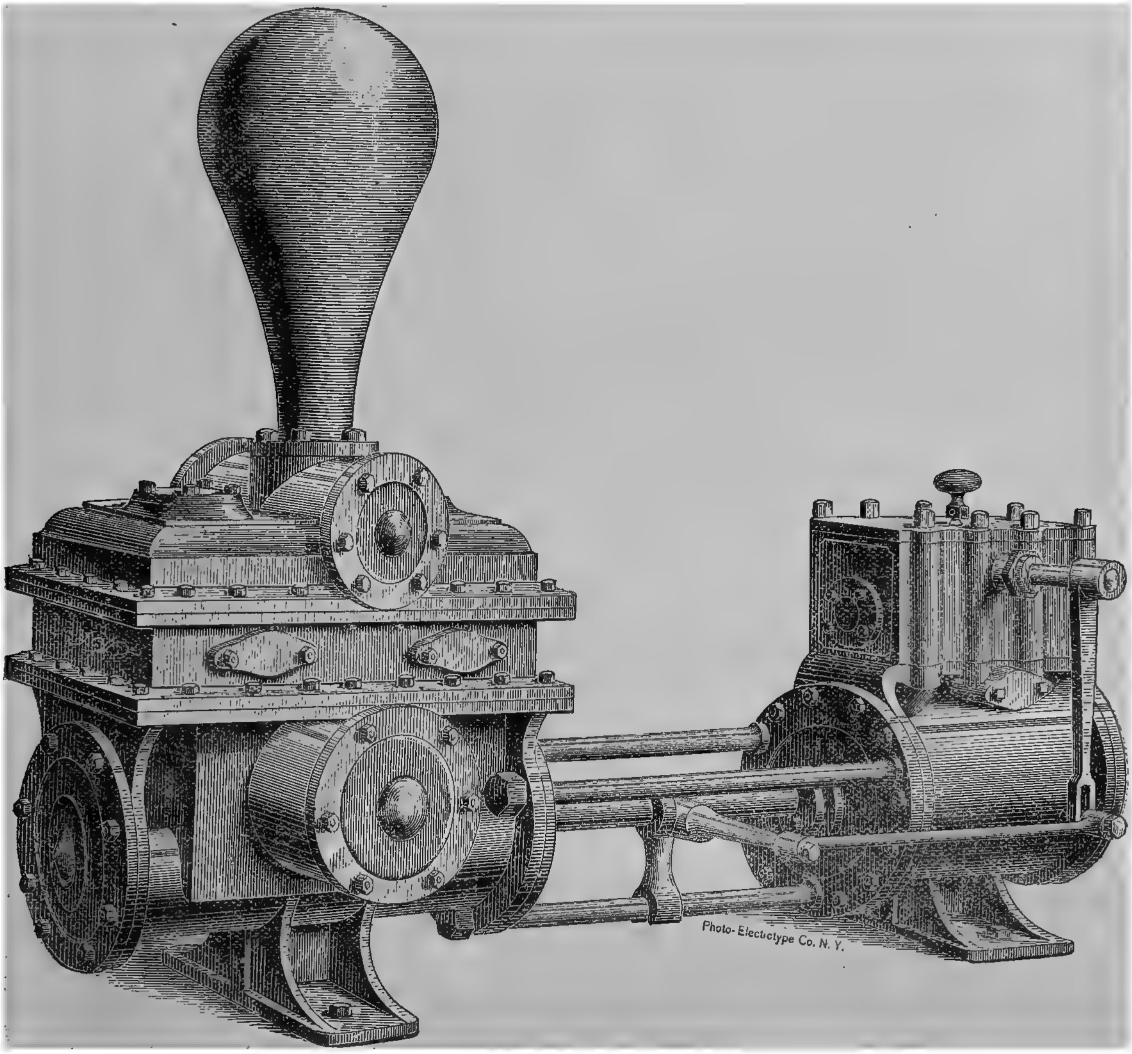

Fig. 39.

of the main piston the main valve is held open by the pressure of steam upon the head of the auxiliary piston. This pressure is opposed by the resistance of the oil to displacement in the cataract-cylinder as the latter is moved by the stroke of the main rod. Should the main piston start too fast, the oil-resistance will overcome the steam-pressure, and the valve will be partly closed. Should it move too slowly, the oil will pass freely through the valve, and the diminished resistance will permit the steam-pressure to give further opening to the main valve.

The cataract-cylinder is of just such a length as to bring its piston against the heads at the proper time to close the exhaust-port from the main cylinder, and to arrest thus the main piston by compression of its exhaust. At the same moment the auxiliary piston receives steam from the small slide-valve. The main valve has a small lap, to permit a small expansion, and to cause an interval between the closure of the port to one end of the cylinder, and the opening of that to the other. By this means also the shock on the water-valves is relieved.

The pump shown in Fig. 39 is also a positively connected pump, permitting a small degree of expansion.

A second great division of this class of steam-pumps will include those in which the hitherto flat surfaces of auxiliary and main valve become the surfaces of cylinders, and the valves either rotate or slide upon their seats, or both.

A typical pump of this class is the pump whose details are shown in Figs. 40 and 41. The tappet-arm causes

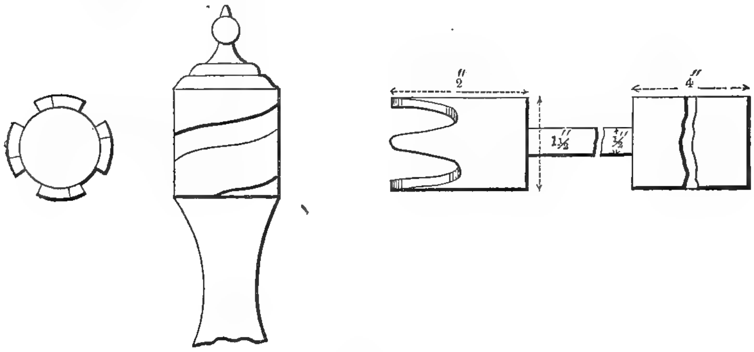

Fig. 40.

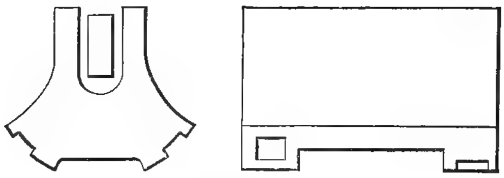

Fig. 41.

a slight rotation of the stem of the auxiliary valve, as the inclined surfaces strike the sides of the forked chocks. A very slight endwise motion will probably be also received. This rotation brings certain cavities in the cylindrical face of the valve into communication with small ports and passages in the wall of the casing, through which steam passes to the heads of the auxiliary cylinder and throws the main valve. The auxiliary piston is cushioned by its own compressed exhaust, and the main piston receives steam-lead. The principal departure from the preceding principles is found in the combining into one valve of the auxiliary and main valves. The rotation of the valve admits steam to the auxiliary cylinder; the axial motion of the same valve admits steam to the main cylinder. The valve is of the Corliss type (Fig. 41), a slide-valve moving on a cylindrical seat, the exhaust-hollow and steam edges being formed in the cylindrical surface of the valve. Similar in principle is the pump shown in Figs. 42, 43, and 44. The valve is of similar form and action, but is moved by the positive link-connection shown. The pendent

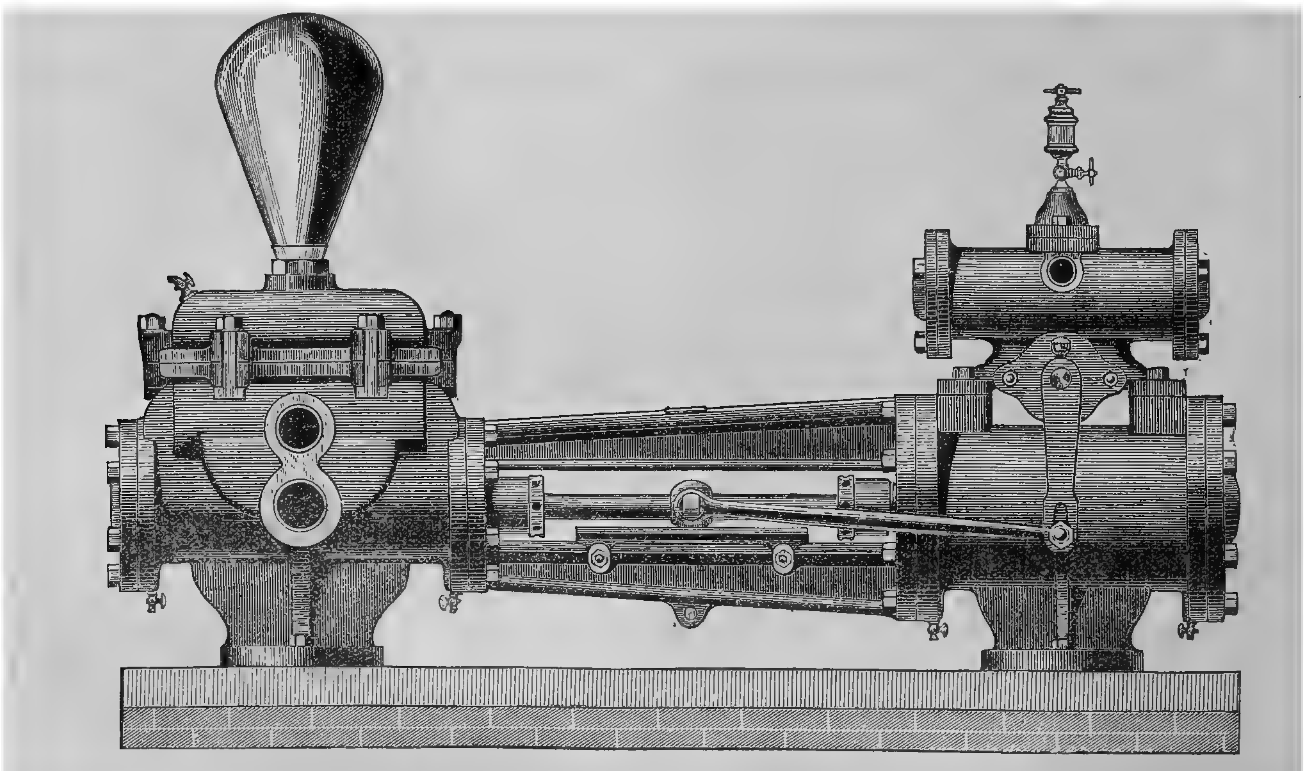

Fig. 42.

arm rotates a cam in the exhaust area (Fig. 44), which consists of a cylinder with a diagonal groove milled out in its convex surface. Into this groove projects a steel pin from the bottom of the valve. This pin will give a slight rotation and trifling end-motion to the valve as the arm oscillates. The rest of the distribution is the same as in the preceding form. The safety-device to insure the throw of the valve is obtained by the length of the slot in the cam. It is short enough to throw the piston, if steam has failed to do so. In the pump shown in Fig. 45 the auxiliary

piston is made to serve as an auxiliary valve. The main piston carries a roller upon a short stud clamped on its side. This roller strikes a curved rocker, concave downward, and centered at its middle point, so that each end of the rocker will be alternately raised and lowered by each stroke of the piston. The oscillation of this rocker is carried

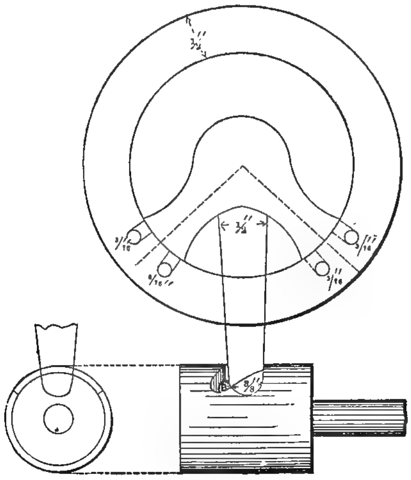

Fig. 43.

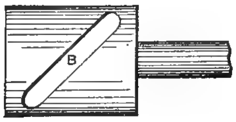

Fig. 44.

to the tappet-rod by a short link fitted with an adjusting sleeve with right and left screws. This tappet-rod is secured to the auxiliary piston, which thus is caused to rotate through a slight angle, determinable by the length of the link. This rotation of the auxiliary piston causes small hollows in its solid part to come opposite to openings in the casing, through which steam enters into the spaces at the heads, causing the piston to reciprocate and to move the main valve. The motion of the auxiliary piston is arrested by the compression of its exhaust after the outlet is covered. The main valve is of the B-form. The steam passages do not reach from the seat to the extreme end of the cylinder, but enter the bore at such a distance from the heads that the main piston covers them before the stroke is completed, and incloses sufficient steam to serve as an efficient cushion and prevent the piston from striking the heads. A separate passage, controllable by a hand-valve, opens to the valve-passages from the ends of

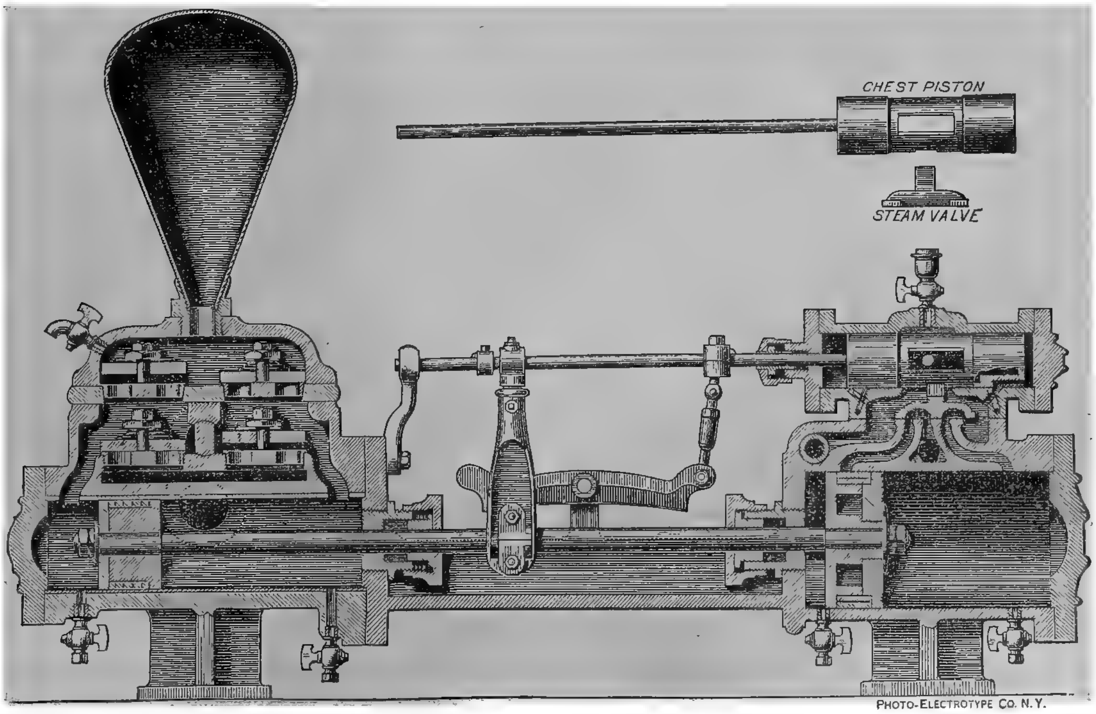

Fig. 45.

the cylinder-bore. By this means the amount of this compression can be reduced when running at slow speeds, or increased to a maximum by closure of the valves when running fast. This addition is very valuable in starting vertical pumps on the Cornish system, or where the resistance may be different on the up and down strokes.

As the main piston covers its own main steam-port at the beginning of each stroke, there has to be an auxiliary steam-port from the main valve-seat communicating with the extreme end of the cylinder. This small port is opened when the auxiliary piston throws the valve and the piston starts slowly on the return stroke. This is

favorable of course to the water-valves. Where the pump is worked with a condenser, there can be no compression of the exhaust to arrest the main piston. In this case steam-lead is given by lengthening the link from the rocker, and the piston is arrested by the live steam. The safety-device in this pump, to insure the motion of the auxiliary piston, consists of a vertical arm clamped to the main rod, which strikes tappets upon the valve-rod, and compels its motion if the steam has not already effected it.

To this general class belong also the pumps made under the Loretz patents, shown in Fig. 46. The auxiliary

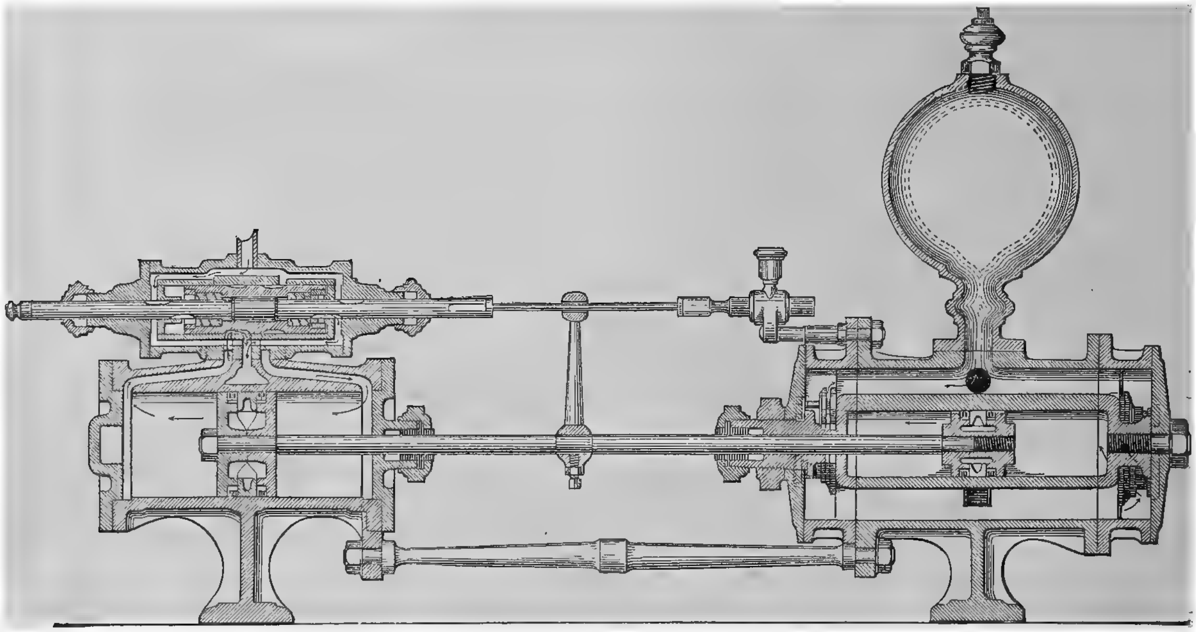

Fig. 46.

piston fits in a jacketed cylinder, and has grooves made in its central part so spaced as to give to it the profile of a B-valve when seen in longitudinal section. Steam entering these grooves can pass to the main steam-passages and

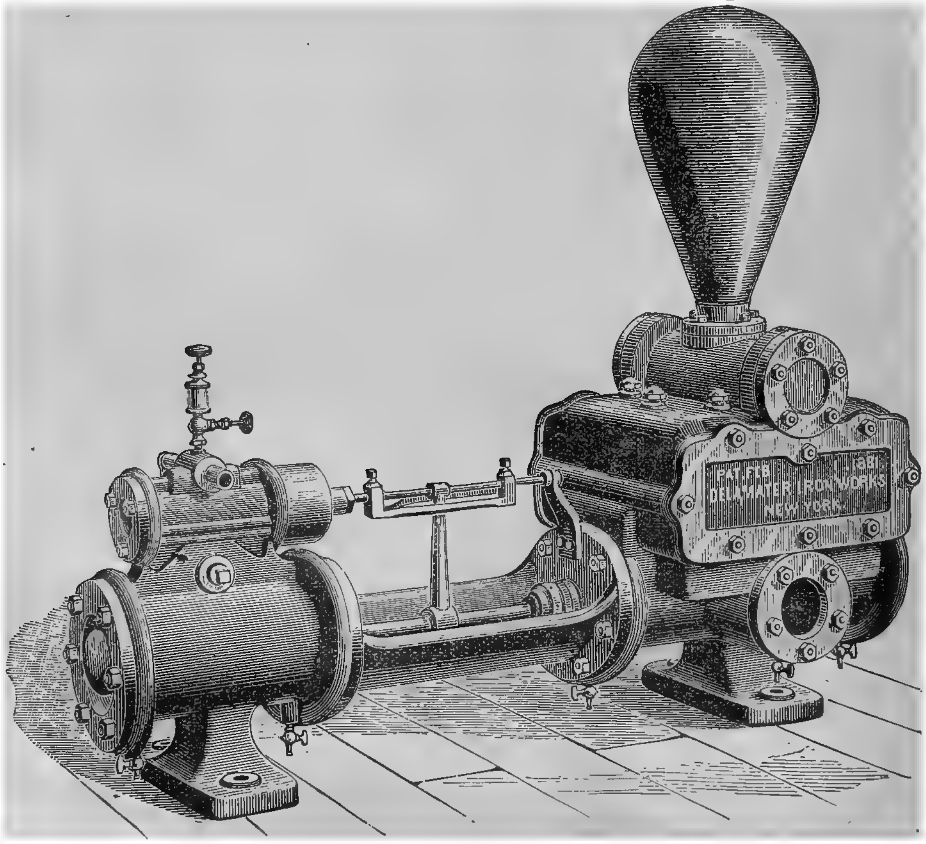

Fig. 47.

move the main piston when the valve is in its proper position. The valve-stem rod is moved by collars when struck by a tappet-arm on the main piston-rod, and the valve-stem is the auxiliary valve. The stem is of larger

diameter than the rod, and has short splines milled out of its surface at proper places, so that steam can pass from the jacket through a drilled passage and the spline, and reach the head of the auxiliary piston, which is also the main valve. At the same time a similar spline and drilled passage below at the other end of the auxiliary cylinder

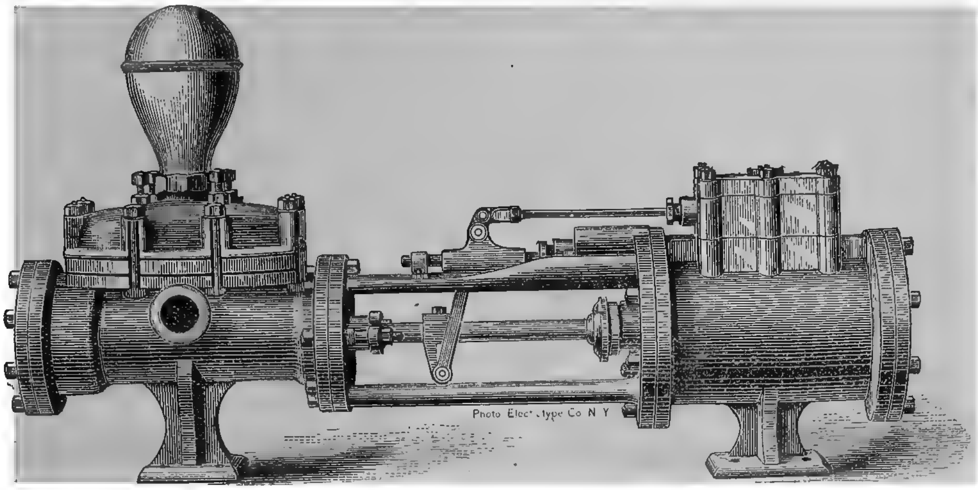

Fig. 48.

opens the space at that end to the exhaust. The piston-valve obeys the excess of pressure, and is thus moved over. The momentum of the valve is arrested by plated steel springs, and the main piston is cushioned by steam-lead. The boss in the middle of the valve-stem will serve to move the valve positively, if steam fails to throw it. To prevent displacement of the splines relative to the planes of their ports, the farther end of the valve-rod is squared and passes through a guide.

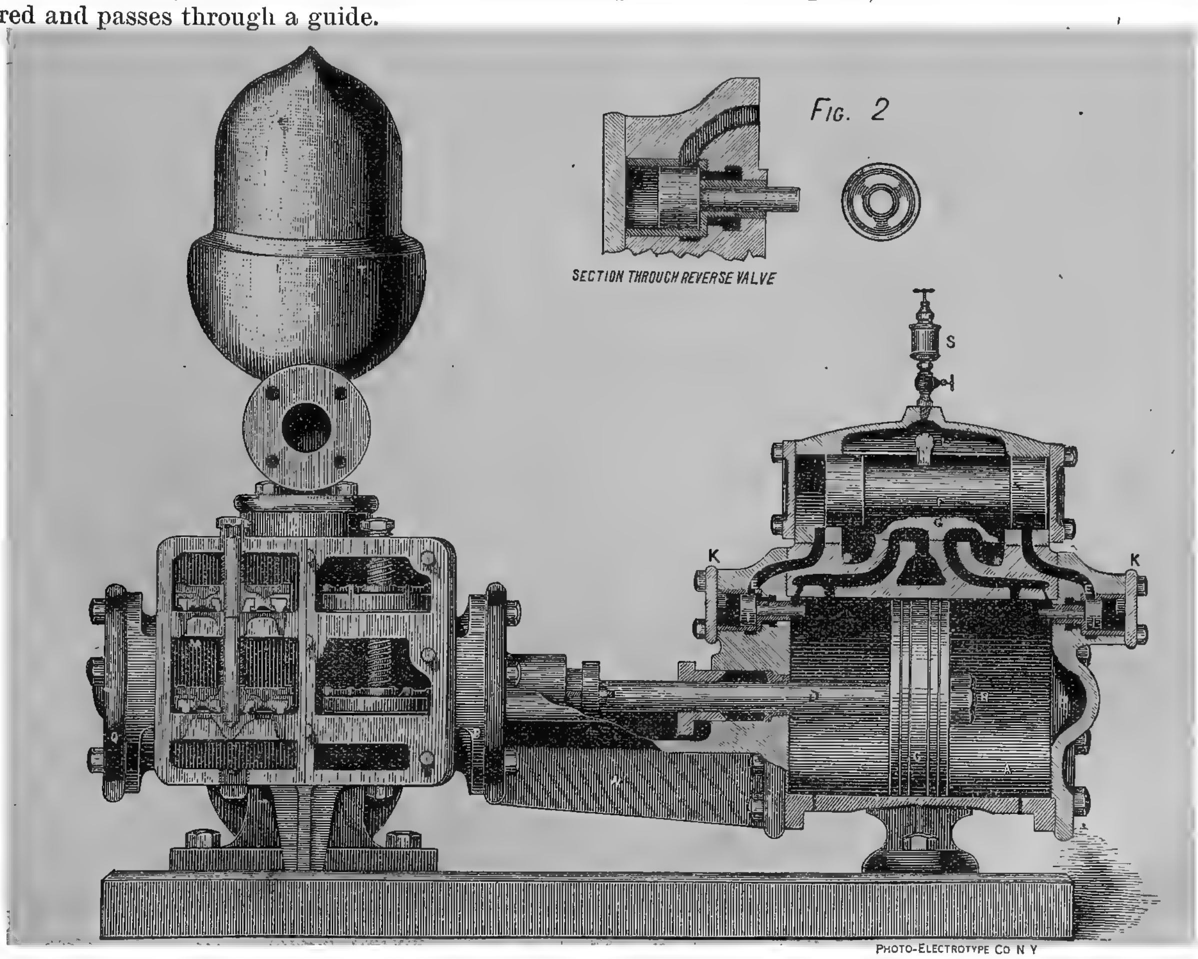

Fig. 49.

The pump shown in Fig. 47 uses the auxiliary piston as the main valve. A vertical arm on the main rod carries two rollers at the sides of its head. These rollers act upon the inclined faces of the brass cradle upon the valve-rod and give a small rotation to the valve. This rotation admits steam to the combined piston and valve, and proper

distribution ensues. There is a departure here from previous forms, in that the auxiliary valve is upon the same axial line as the main valve. This is also shown in the Gaskill pump (Fig. 48), although here all the parts are present. The auxiliary piston is in front of the main valve and its chest.

The third class of valve-gear for direct-acting pumps embraces those in which the main piston is brought in to play a part in actuating its own valve-gear. Such a pump is the one shown in Fig. 49. The steam-piston, at the end of its stroke, strikes the end of the stem of a poppet-valve. The opening of this valve connects the space at the head of the auxiliary piston at that end with the exhaust. The other head has the steam pressure upon it, and the auxiliary piston obeys the excess of pressure, and throws over the main valve. The poppet-valve closes when released by the main piston, by the pressure of steam upon its back, equilibriating the pressures upon the auxiliary piston till the end of the stroke in the opposite direction. Minute openings in the heads of the auxiliary piston

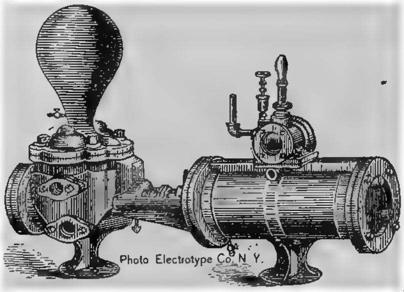

Fig. 50.

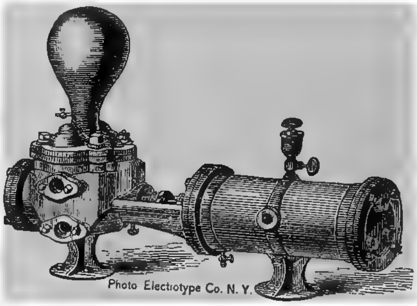

Fig. 51.

permit live steam to leak into the spaces beyond its heads, and the position in the bore of the small ports to the exhaust cause the cushioning of its motion by compression. The main piston is also cushioned by compression of its exhaust. Small ports to the extreme end of the counter-bore admit sufficient steam to start the pump slowly till the larger ports are uncovered.

This arrangement permits very "short-connected" pumps to be used. The same builders design also a pump with a long stroke. The advantage sought by the length of stroke is a large capacity with diminished number of reciprocations. There is a loss when the direction in which the fluid is moving is changed very often.

A pump called the "rock-shaft" pump has the auxiliary valve moved by a finger resting between ridges on its back. The motion of the finger is transverse to the axis of the main cylinder. This finger is attached to a rock-shaft, parallel to the axis of the cylinder, and at one side. A curved arm attached to it projects slightly into the

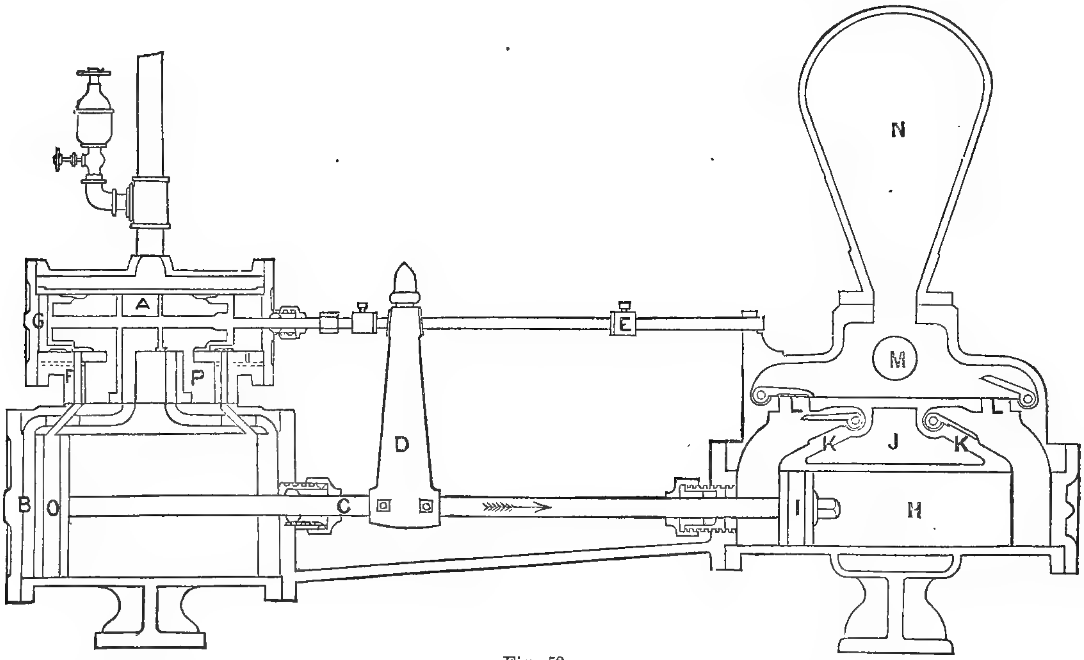

Fig. 52.

bore of the main cylinder at each end, and is so placed that the main piston will strike an incline upon the arm and lift it just before the end of each stroke. The auxiliary valve-openings permit steam to throw the valve at the proper points. The same builders also make what is known as their "differential motion" and their "middle segment" pumps. They are short-connected pumps and, like the first form illustrated, have no fragile external parts (Figs. 50 and 51).

In the pump shown in Fig. 52 the main piston acts somewhat as the auxiliary valve. Live steam enters a jacket around the casing of the cylindrical piston-valve, and passes thence into the space between the heads. From

these the steam may enter the main ports when they are uncovered. A tappet-arm on the main piston-rod moves this valve so that a groove in it comes opposite a hole drilled into the main cylinder in the top of its bore. This groove fills with the steam which is still driving the main piston, and which can now pass through a small horizontal passage through the auxiliary piston-head to the space beyond it. The space at the other end of the auxiliary cylinder is by the same motion of the valve put in communication with the exhaust, and the piston, obeying the excess of pressure, moves over and opens the ports for the return stroke. The auxiliary piston and main valve is cushioned by its own exhaust, since the main piston covers the small passage at the other end before its throw is completed. The main piston is cushioned by steam-lead.

To one or the other of these several types, the so-called direct-acting pumps in use at this date will be found to belong. As a type, the direct-acting pump is preferred and mostly used at the east. It has been introduced and successfully applied in mining practice, and a very large number is in use for boiler-feeders and for tank-service. The several valve-motions are also used in designs of pumps for special services, such as air-pumps, elevator-pumps, fire-pumps, etc. The modifications made upon the typical design for such cases are in relative proportions only, and not at all in fundamental principles. These remain unchanged in all the varieties of form.

3.—DUPLEX PUMPS.

The principle underlying the duplex pumps is an extension of the fundamental principle of the direct-acting pumps. The piston-rod of a pump of the latter class opens a valve admitting steam to a second piston, which again causes the admission of steam to the first piston. In the duplex pump the second piston becomes as large as the first and is made to drive a water-piston. The auxiliary engine becomes a second pump, and will be placed at the side of the other. Hence there will be two equal steam-cylinders side by side and two water-cylinders, the piston-rods of each being continuous. Upon each rod is clamped a stud which moves an arm hanging from a rock-shaft (Fig. 53).

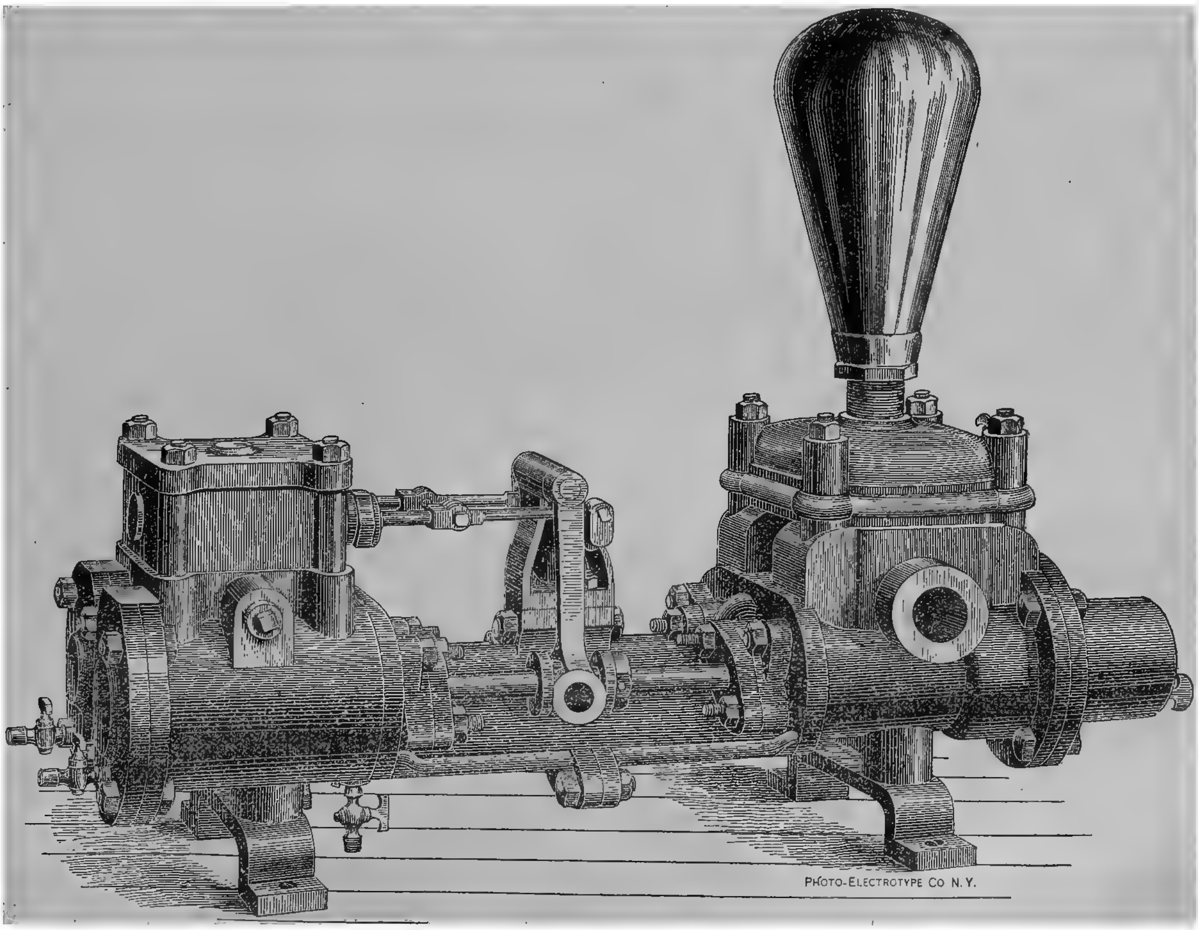

Fig. 53.

The vibrating motion of this arm as driven by the piston-rod of each pump is transmitted to move the slide-valve of the other pump, through a short arm and jointed valve-rod. By this means it becomes possible to arrest the motion of each piston by the compression of its exhaust, which causes a short interval of rest for the water-piston, during which the water-valves may seat themselves without jar. The method of effecting this exhaust-compression

is shown in Fig. 54. There are two passages to each end of the cylinder. Both act as exhaust-ports, but the slide-valve is so proportioned that only the outer one admits live steam. The outer port is first closed by the valve on the exhaust-stroke, and then the inner one is closed by the piston itself. Compression of the included steam

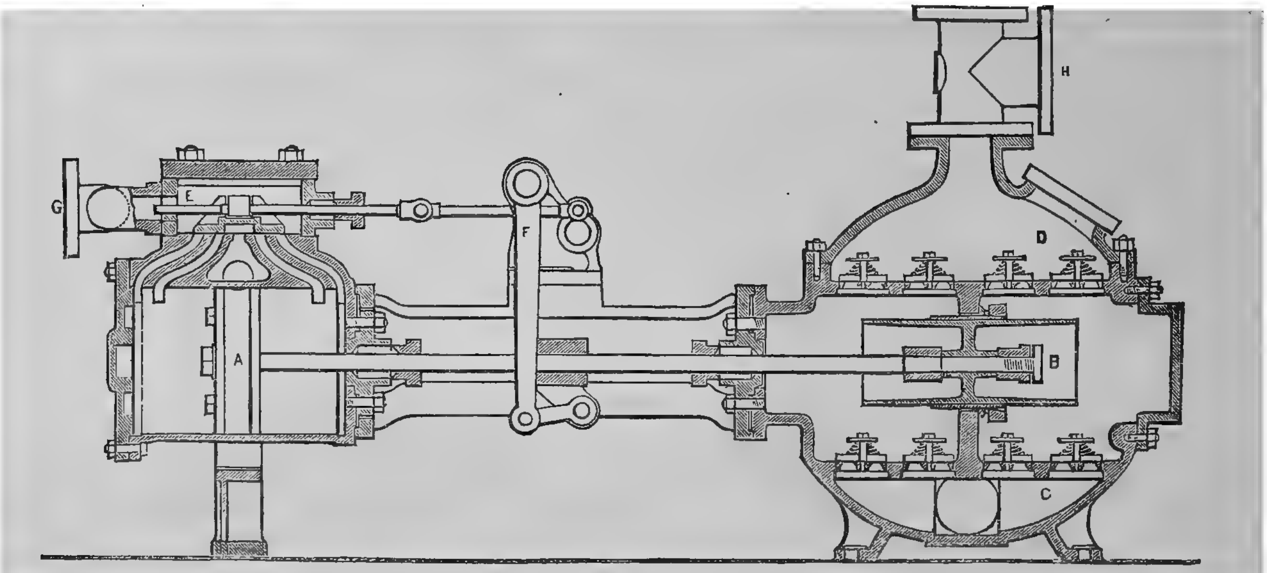

Fig. 54.

must result, arresting the piston. This is the same principle which is applied to cushion the motion of so many auxiliary pistons in the direct-acting pumps. In the larger designs a special bunter-valve is often put upon the cylinder-heads, kept to its seat by boiler-pressure upon its back. Should the piston come too near the head, it strikes the spindle of this valve and insures an independent steam-lead. This, of course, will only occur in case of accident, the valve remaining shut in regular working.

By this duplex system, also, there can be no danger of stalling at even the lowest speeds. When one piston stops it must have moved the admission-valve of the other, and thus must have set the other piston moving. The pumps must, therefore, start as soon as steam is turned on.

This system, moreover, has the advantages which inhere in the positive connection between the piston and its auxiliary valve. The slide-valves, which are of the B-form, move quietly and without shock.

The arrangement of the valves and plungers compels a steady flow in the delivery-pipe, thus diminishing or avoiding entirely the shocks produced in any other system from intermittent pulsations.

The duplex design is due, as a system, to the late Mr. Henry R. Worthington, of New York. Other makers at this date, however, are putting pumps of this type upon the market. They have met their special application in working under heavy loads, as in water-works, mines, oil-pipe lines, and for hydraulic machinery, for which their steady motion peculiarly fits them.

4.—CAM PUMPS.

The fourth general class of pumps includes what are known as cam pumps. They are of different classes.

The pump shown in Fig. 55 has its valve thrown by steam by means of an auxiliary piston. This piston is moved when a small slide-valve at the side of the auxiliary cylinder opens a connection between the space at the head of the piston and the exhaust-passages. The auxiliary piston responds at once to the unbalanced pressure and moves the main valve. The valve-rod for the auxiliary valve is attached to the end of a rocking lever, pivoted upon a lug in the middle of the cradle between the two cylinders. The lower end of this rocking lever is extended in a T-form, so as to include the profiles of a grooved cam, upon whose acting surfaces bears a horizontal roller. The axis of this roller is a stud clamped to the main piston-rod. It will be at once seen that the profile of this grooved cam can be so shaped at the two ends as to move the auxiliary valve just before the end of each stroke, and thus to reverse the pump. But the intermediate part of the profile has a special function in this design. After a greater or less length of time in many pumps, the auxiliary piston wears loose in its bore, and boiler-steam is continually leaking through the auxiliary ports into the exhaust. To prevent this loss in this type of pump, as soon as the piston has reversed its motion and the roller leaves the steep part of the cam, it strikes the straight lower profile, and thus brings back the auxiliary valve to its central position. This closes all the auxiliary ports, and keeps them closed until the stroke is completed. Then the curves of the cam open the exhaust-connection as before to the other end.

In addition to accomplishing the desired object of preventing leakage, by this system of actuation of the auxiliary valve, is avoided the shock of impact against collars which is to be observed at high speeds in so many designs.

The cam-pump shown in Fig. 56, uses a plain slide-valve and avoids the complication of the auxiliary cylinder and attachments. The valve-rod is connected by a short link to a short arm upon a rock-shaft. This shaft rotates in bearings upon both sides of the cradle. To the shaft in its central portion is secured a long arm which extends

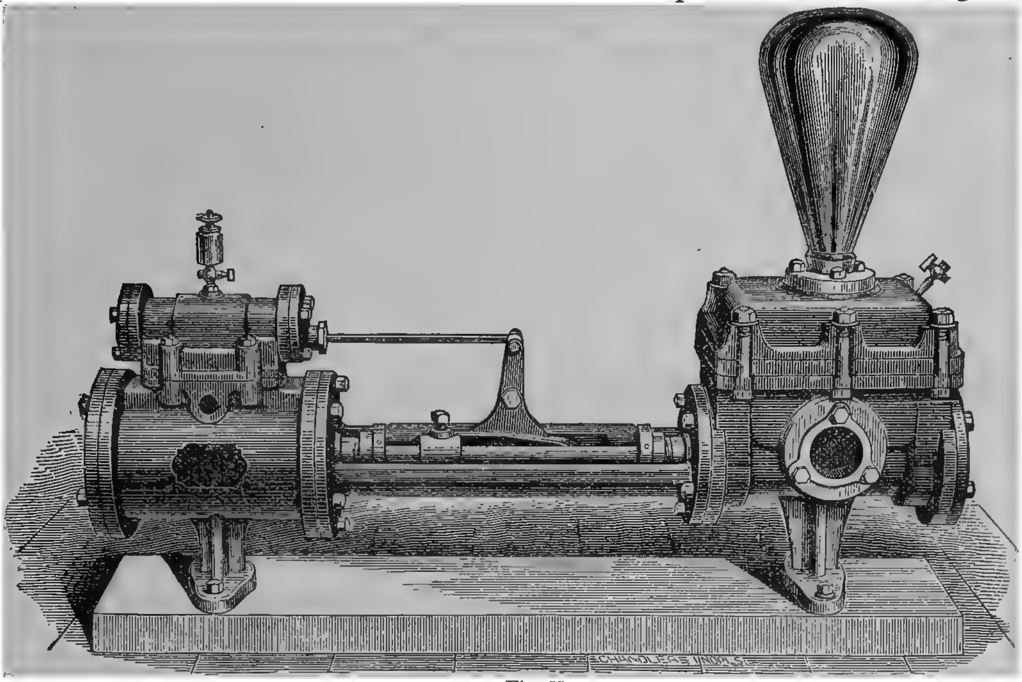

Fig. 55.

out horizontally to be acted upon by the cam. The cam-casting is secured to the piston-rod at its middle point, the acting profiles being the edges of grooves shaped upon its side. These grooves act upon the long arm of the rock-shaft, through a horizontal friction-roller upon a stud at the end. The grooves of this cam are so constructed as to cause the admission of steam to be greatest at the middle of the stroke, while but a small port-opening is permitted

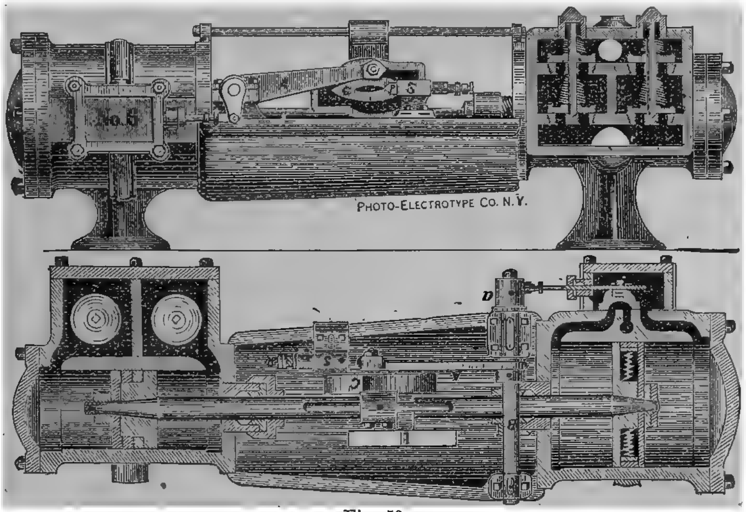

Fig. 56.

at its beginning and end. In order to prevent stalling at the ends of the stroke, a well-known and efficient device is used. The end of the long arm of the rock-shaft is made wedge-pointed horizontally. As the curve of the cam raises or lowers the end of the arm, it brings this wedge-point against the incline of a similar horizontal wedge-point upon a short spindle. This spindle moves in guides upon one side of the cradle. The end of the arm acting upward or downward upon the inclined face of the movable wedge, tends to force it back in order that the arm may pass by. The motion of the spindle is resisted by a spiral steel spring. It is practically impossible for these two wedges to hold each other caught upon their sharp edges, which is the relation corresponding to the central position of the slide-valve. The spring upon the spindle is strong enough (with the leverage which it has) to throw the rocker-arm in the direction in which it is free to move, and thus opens a small port-passage. This small opening will start the pump slowly, bringing the cam to act on the valve and control it for complete distribution. The stiffness of the throw-over spring is controllable by jam-nuts.

In large pumps for heavy duty the spring for the driving-wedge is given by boiler-steam acting upon a piston upon the spindle. By this means the heavier the pressure upon the back of the valve, the stronger is the spring to overcome the resistance.

5.—SPRING-PUMPS.

To this class belong those pumps in which the throw of the valve is completed by the action of a spring which has been strained by the motion previously made. Such an one is the pump shown in Figs. 57 and 58. The steam-valve is of the piston-pattern, exhausting at the ends. It is therefore balanced and should move easily upon its seat. There are two chocks upon the valve-rod which are moved by a tappet-arm, and will carry the valve into

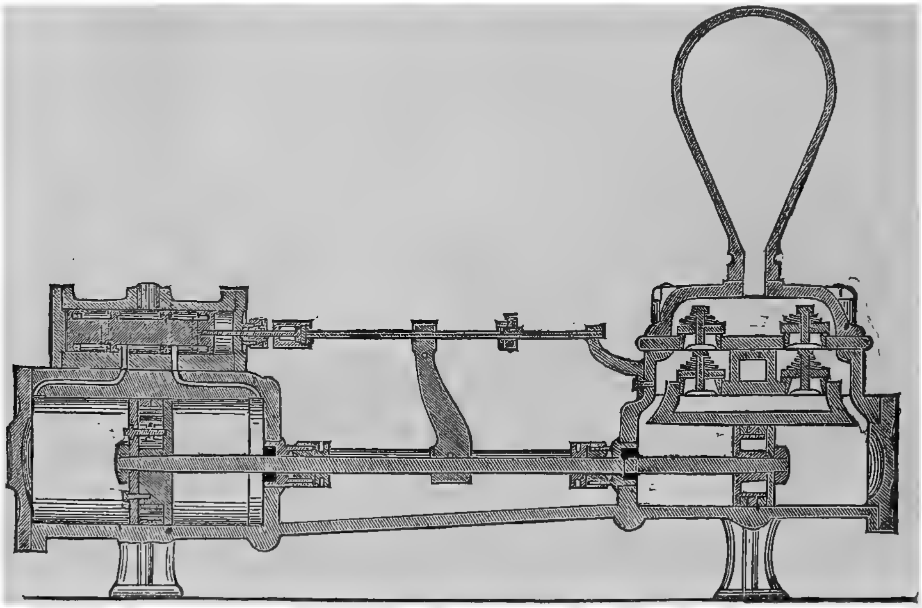

Fig. 57.

its central position. It is prevented from remaining over both ports by the arrangement of two short links and a pair of elastic steel arms. The latter are secured by one end to the sides of the valve-chest, parallel to the rod, and the free ends are jointed to the links, which in turn are jointed to a collar upon the rod. The length of the links is such that, when they are at right angles to the rod the steel arms will be bent back, and therefore under strain. It will be seen that in any other position than at *exact* right angles, the strain of the springs will tend to

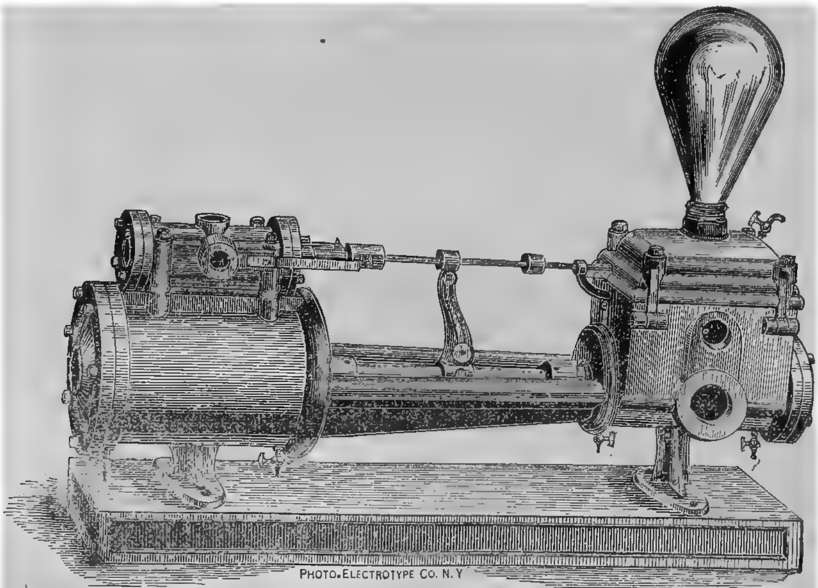

Fig. 58.

move the valve-rod lengthwise, since by no other motion can the springs be released. Since it is very improbable that the main piston will stop with the strain upon the links at exact right angles with the valve-rod, the springs will complete the throw of the valve and the pump will reverse.

This type of gear is historically an early one. It will not be found very widely upon the market at this time.

In concluding the discussion upon the reciprocating pumps, it is to be observed that they are essentially positive in their displacing action upon fluids. They will therefore find their application for forcing under high heads or great resistances, even with a considerable lift. It is best, however, that the fluid to be displaced should flow easily, and that it should not contain a very large proportion of solids. For such material a different form may be preferable.

Class B.—ROTARY PUMPS.

The various types of rotary pumps may be examined under three classes:

I. Rotary piston-pumps.
II. Centrifugal pumps.
III. Propeller pumps.

The essential parts of a rotary pump are comparatively few. In a casing of cylindrical shape, or made up of parts of cylindrical surfaces, will revolve one or more pistons. These will be driven from an external shaft which enters the casing through stuffing-boxes in the heads. There must also be an abutment to separate the sucking and forcing sides of the pump. This will, of course, be movable, and will either be driven by gearing outside, or its motion will be compelled by the internal structure of the machine. Any rotary engine may be turned into a rotary pump by the simplest inversion. There are certain forms in use at this date, especially for pumping purposes, to which attention will be drawn.

The centrifugal pumps, however, depend upon a different principle. Their function is simply to produce a motion in the fluid, which shall cause certain natural forces to come into play, whose action shall produce the desired displacement. Hence there will be no displacing pistons nor any abutment.

The propeller pumps simply apply the principle of the screw to the raising of a fluid, in which as a nut the screw shall be made to revolve. In all these cases it will be seen that no valves are necessary, except possibly a foot-valve at the bottom of the suction-pipe, and only in a few types will any air-chamber be called for.

1.—ROTARY PUMPS.

The rotary pump most generally in use is the Holly pump, illustrated in Figs. 59 and 102. There are two

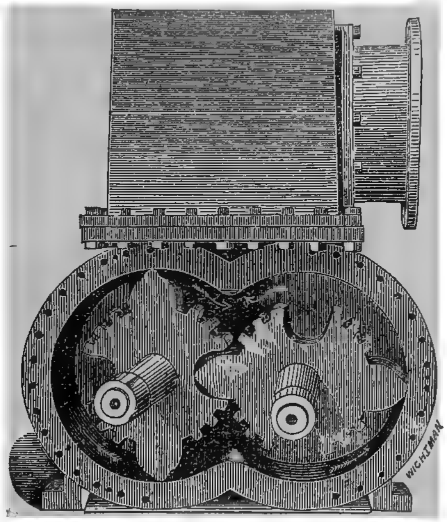

Fig. 59.

revolving shafts geared together externally, which carry the two revolving pistons in the chamber. Each of these serves as abutment for the other from its shape, and the joints are made water-tight by packing strips in the ends

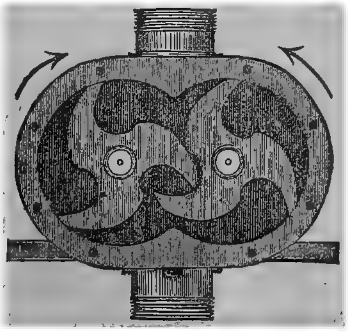

Fig. 60.

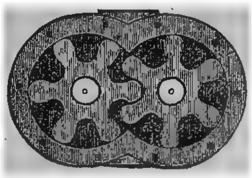

Fig. 61.

of the arms of the spider. These strips have an offset to keep them from being forced out when not in contact with

the casing, and are kept to their work by flat springs. When the pistons are made to revolve in the direction of the arrows, it will be at once seen that rarefaction of the air in the suction-pipe must ensue, and atmospheric pressure will ultimately cause the water to enter the spaces between the pistons. This water will be displaced by the arm following and forced into the space above, from which the only outlet is through the discharge-pipe. The flow will be continuous, or with but slight pulsations, and of course no valves are required.

Another type using two pistons is shown by the pump illustrated in Fig. 60. Here the action of the parts is the same, the arms of the spider being more curved. The profiles of the pistons as in the former case are so shaped as to be complementary each of the other, so as to be always in contact along the center line.

Similar in action is the pump made by the same firm illustrated by Fig. 61. The curves of the pistons are epicycloidal, and fit completely the spaces opposite as they pass successively the center line. This type avoids the necessity of gearing outside.

The pump of Fig. 62 shows a similar type of construction. The curves of each piston clear the prominent

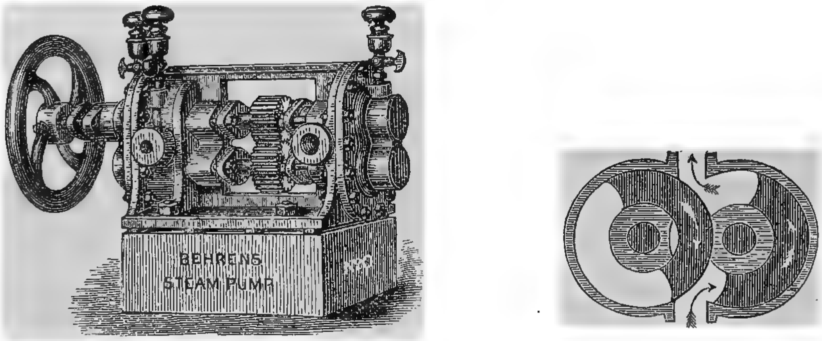

Fig. 62.

profiles of the other.

There are several designs in which the abutment is distinctly present, instead of being concealed in the second piston. Such an one is shown by Fig. 63 of the Torrent pump. The large lower piston fits without clearance into

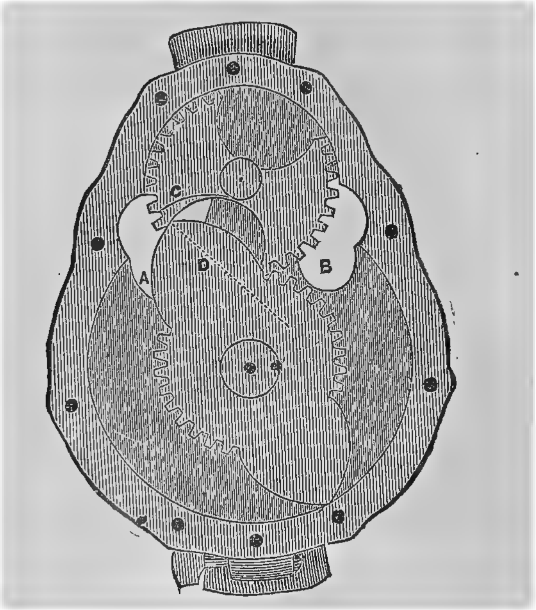

Fig. 63.

the hollows of the abutment above, or else the division is effected by the contact of the toothed surfaces along their line of centers. A departure from previous types is made by having the inlet and the outlet orifices upon the side of the casing and not at the bottom and the top. By this means is avoided the necessity of having a leak into the suction for the fluid which would be forced from the abutment space by the long tooth of the piston. The piston and the abutment must be geared together externally.

In the Foster pump, illustrated in Fig. 64, there are four radial pistons revolving in contact with the casing, and the solid center which drives them serves as an abutment. The center is eccentric to the casing so that it remains in contact with it at one line, and the pistons slide in and out as compelled by their tangency to the casing. They retreat inside the abutment as they pass the point of its tangency with the casing.

Still another type is shown by the pump of Fig. 65. The displacement is here effected between the casing and the eccentric revolving ring. The latter is driven by a belt-wheel outside and no gearing is required. The

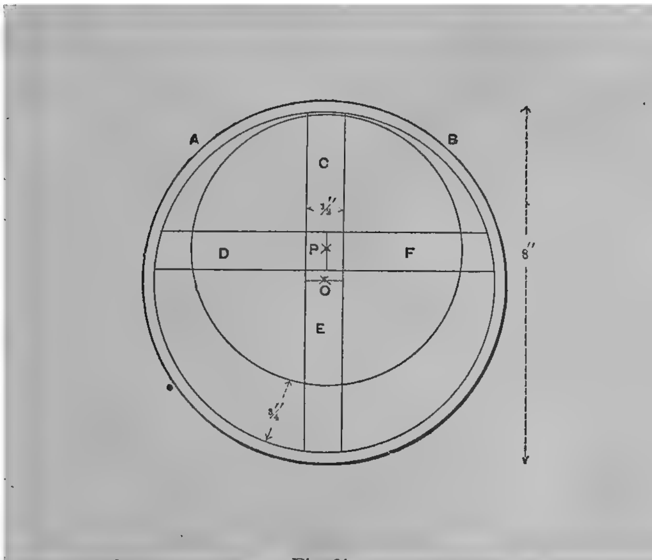

Fig. 64 *a*.

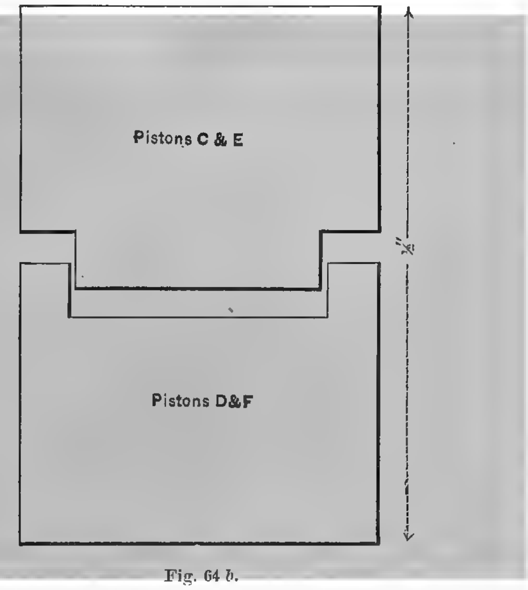

Fig. 64 *b*.

abutment is here made by a slide-valve, the eccentric ring sliding through the middle of the valve and thus moving it upon its seat. The delivery outlet is upon one side of this valve and the suction inlet I is upon the other. In

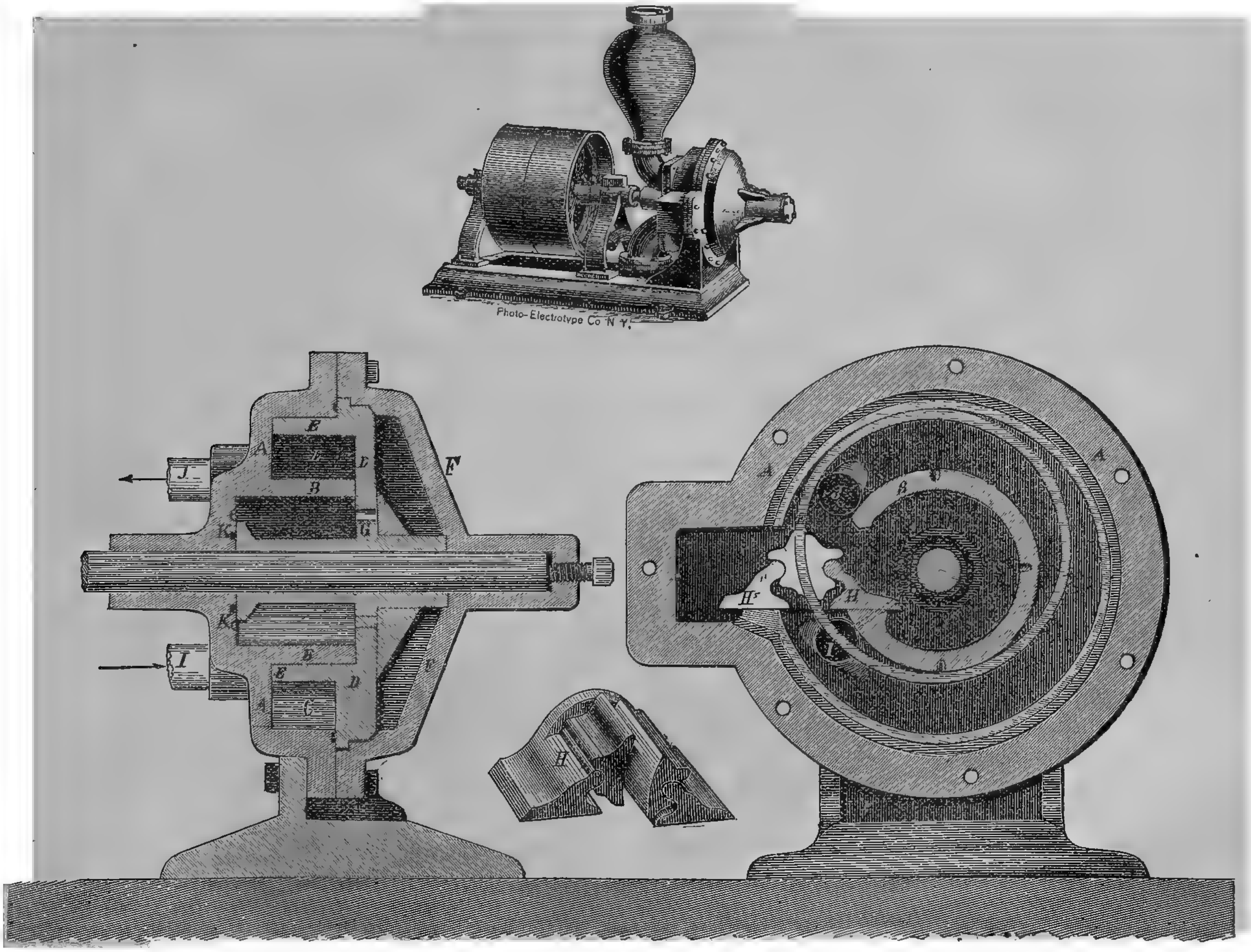

Fig. 65.

newer forms the abutment-slide is at the top of the casing, so that the pump can be driven in either direction, either outlet serving as delivery-vent.

In the pump shown in Fig. 66 still a different type is presented. The chamber is divided into three parts, in each of which is revolved a spur-gear of five teeth. These gears are revolved by the pin-plate, which has seventeen pins upon it, which engage in the gears and positively displace the contents of the spaces between the teeth into the

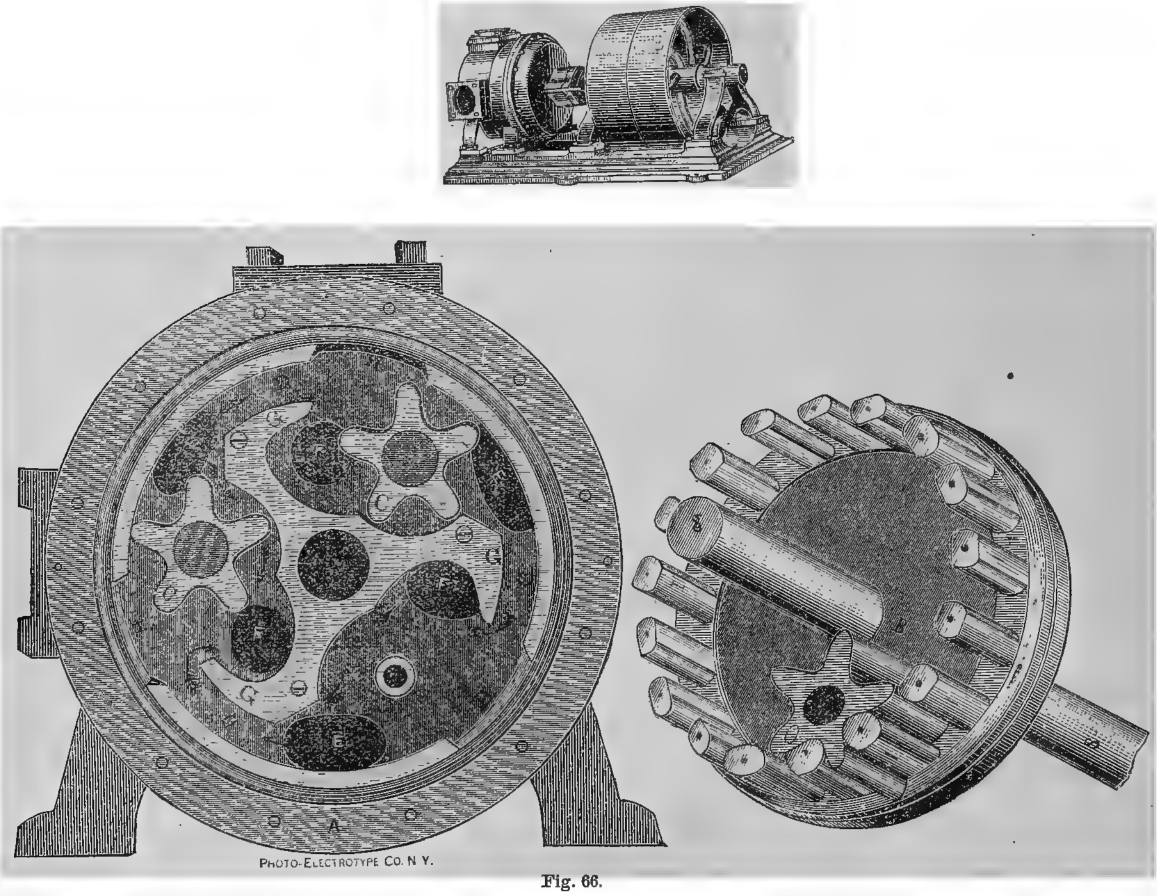

Fig. 66.

delivery-pipe. The arrows show the course of the fluid. The number of teeth in the pin-plate is made seventeen in order that it might be a prime number to five, and prevent pulsations in the flow. The pin-plate is driven by a belt-wheel, and is balanced against the end pressure of the forcing-column by a film of fluid. The gears fit upon hollow studs which are filled with tallow. In the event of heating, some of this tallow will melt and lubricate the rubbing surfaces.

2.—CENTRIFUGAL PUMPS.

In the centrifugal pump there is but one moving part. A wheel with a number of arms revolves rapidly within a casing. These arms are so shaped as to put the fluid into motion along the radii of the wheel, and cause it to have a centrifugal tendency when it leaves the arm. The casing receives a scroll-shape so as to favor this

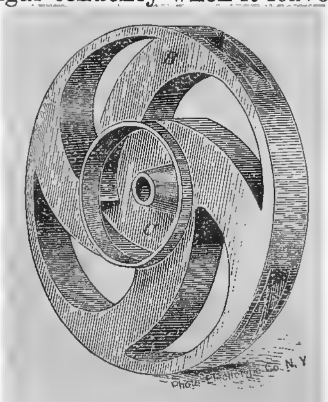
Fig. 67.

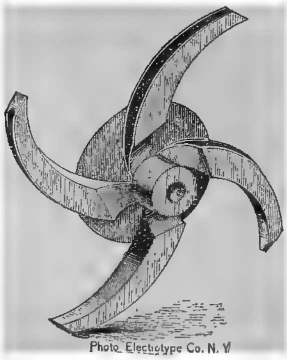

Fig. 68.

centrifugal tendency. The space at the center of the wheel being thus left void, the pressure of the atmosphere forces fluid to fill it through the suction-pipe and the process repeats itself. The fluid in the rising column is continually displaced by the effort of the fluid within the casing.

The general type of wheel used in pumps of this class is shown in the four figures, 67, 68, 69, and 70. The

arms are essentially spirals to allow for the two motions of every particle of water within the wheel. It moves in the direction of the radius and also revolves with the wheel. The hollow arm (Fig. 67) is best for water and most

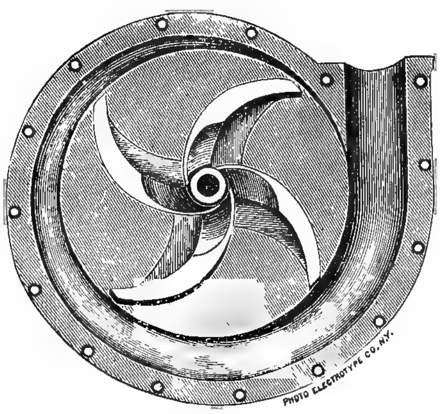

Fig. 69.

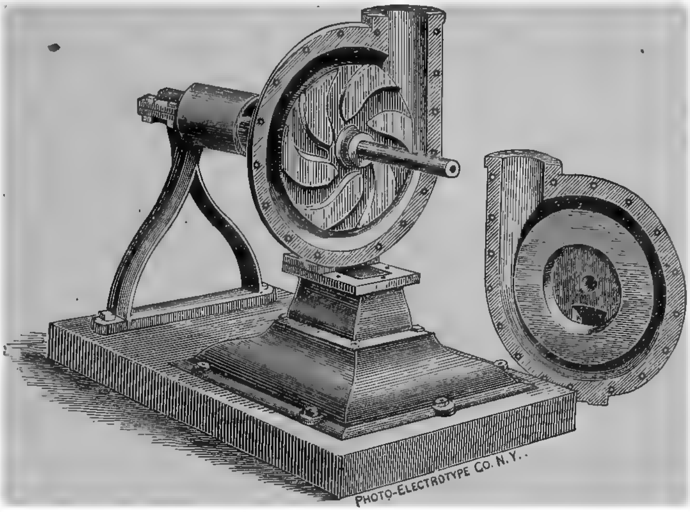

Fig. 70.

other fluids, the solid arm (Fig. 68) being used for viscous fluids or for services where there are ropy matters to be

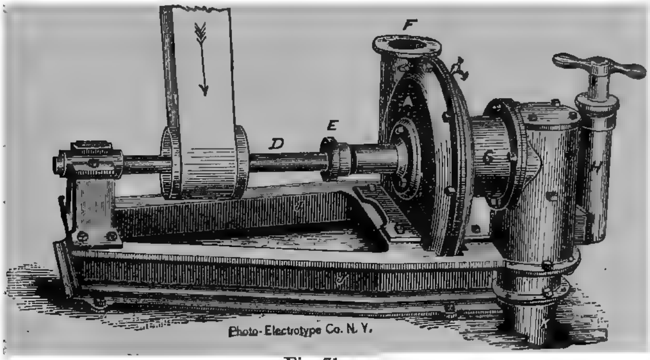

Fig. 71.

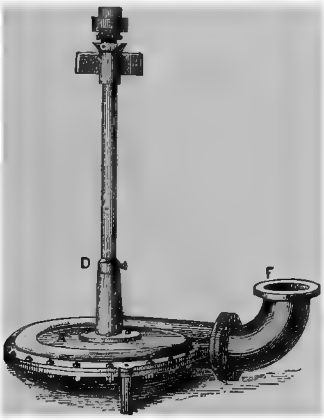

Fig. 72.

displaced. The third form (Fig. 69) has sharp edges to disintegrate such material and render more easy its passage through the wheel.

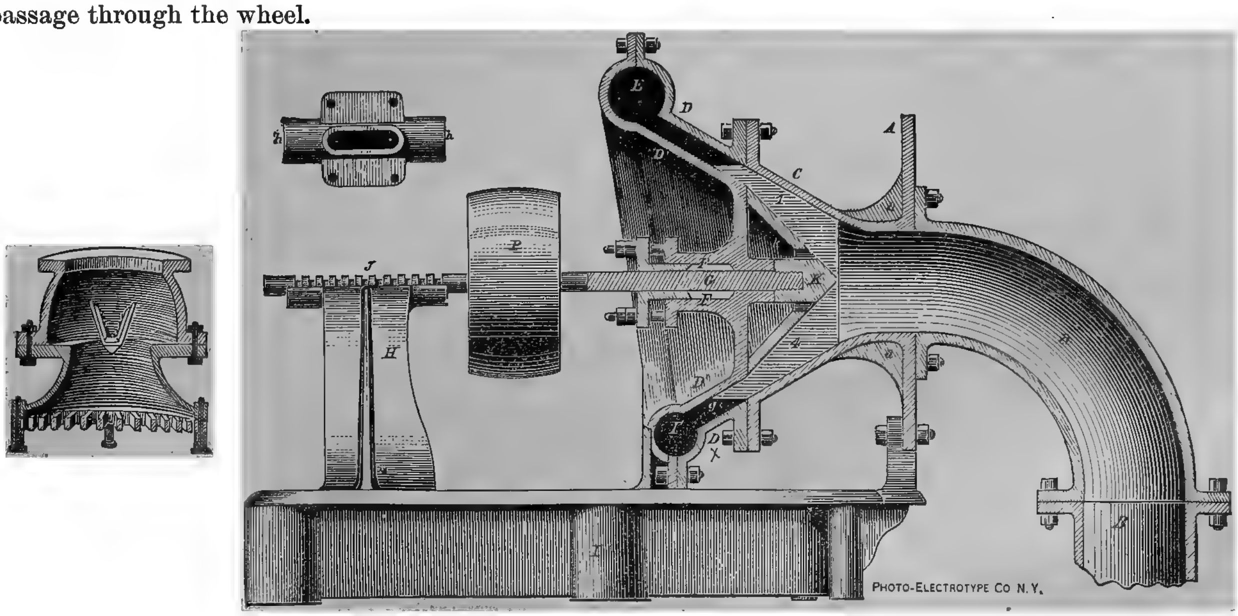

Fig. 73.

These pumps may be used upon a horizontal or a vertical shaft (Figs. 71 and 72). The latter arrangement has certain advantages, since the pump can be put at the bottom of the area to be drained. These pumps, when used

to lift for any distance, require to be primed by filling the suction-pipe before starting. To this end a hand-pump is put at the elbow of the suction-pipe to exhaust the air and fill the pump (Fig. 71).

The centrifugal pump shown in Fig. 73 has a wheel with straight blades, which radiate from the surface of the frustum of a cone. The fluid enters at the smaller base to leave the wheel at the larger base with a centrifugal tendency. The chamber into which it enters is of the scroll form, being gradually enlarged till the full discharge-area is obtained. The wheel revolves upon a horizontal shaft, so that there is but little loss from friction of fluid in turning corners. The driving shaft is carried by bearings and stuffing-box out through the side of the casing, and the strain on the driving-pulley is partly carried by the casing. But a small portion of the flexing effort is borne by the shaft in one form. A coupling is secured on the shaft, and this coupling is bolted to the end of the hub of the pulley. The pulley turns upon a hollow sleeve bolted upon the casing through the center of which passes the shaft. There is no thrust upon the wheel, except that due to the atmospheric pressure against the vacuum, and even this can be overcome by small passages connecting the two sides of the cone. Fig. 73 shows a design with a thrust-bearing.

3.—PROPELLER PUMPS.

In the propeller pumps the blades are portions of a screw. As they are made to revolve, the water is continually forced up the inclines of their faces, and is thus continuously displaced.

In the type shown by the pump of Fig. 74, the axis of the screw is horizontal, and it is driven by a belt. The

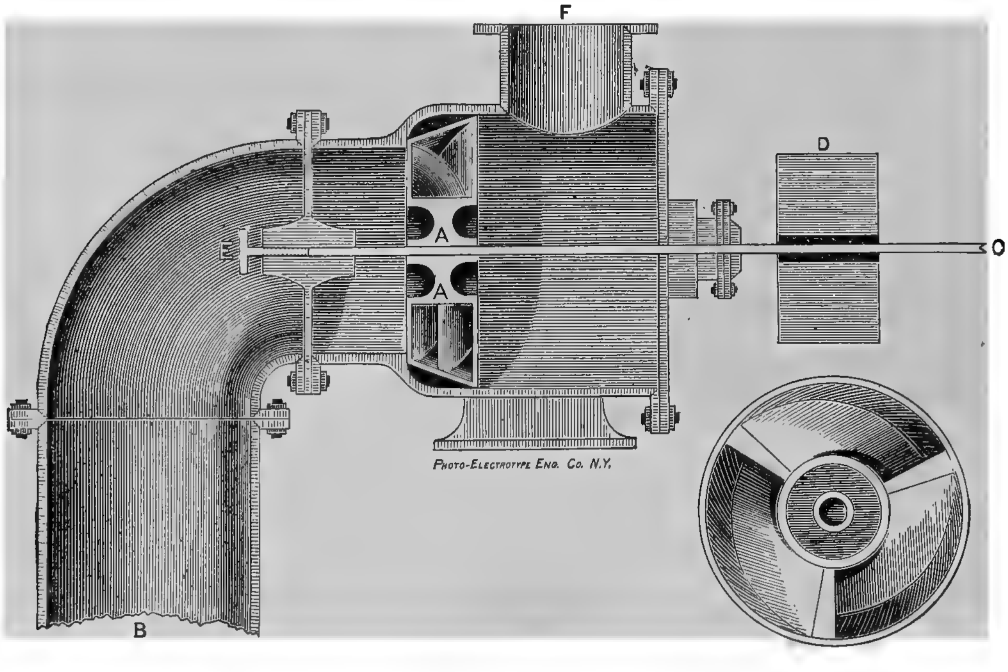

Fig. 74.

thrust of the water-column is borne by a step-screw in the diaphragm at the elbow. In the Shaw pump, illustrated in Figs. 75 and 76, the axis is vertical, and there is a series of helical blades at intervals all the way down the lifting-pipe. The shaft is steadied by bearings at suitable intervals, perhaps five feet apart. There are also fixed blades upon the walls of the rising-pipe, which should diminish the rotative tendency of the ascending column. The upper end of the pump terminates in an elbow, through which protrudes the shaft to receive a belt-wheel. To resist the thrust of the lift and to carry the weight of the shaft and its attachments in the larger sizes, is the object of an especial apparatus. There is attached to the revolving shaft a horizontal disk, which turns with it (Fig. 76). Between this disk and a stationary one just below it, water is forced in at a pressure just sufficient to lift the upper disk from the lower, so that it revolves upon a thin film of water. This makes its motion practically frictionless at this point. The escape of this water laterally is prevented by an annular piston with ring packing, but if the water-pressure lift the disk too high, the excess escapes over the top and returns to the forcing-pump barrel. The whole is protected by a dome-casting.

The propeller pumps will not lift by aspiration. They must, therefore, be put down close to the surface of the fluid, and work entirely by the lifting action of the blades.

The centrifugal and the propeller pumps are especially adapted for moving large quantities of fluid under small heads of lifting or forcing. The rotary pumps will deliver under greater pressures, but can move only smaller

volumes. The absence of valves and the forms of the passages adapt them all for moving fluids in which solid matter may be present. They will, therefore, be employed for draining and wrecking purposes. When it is

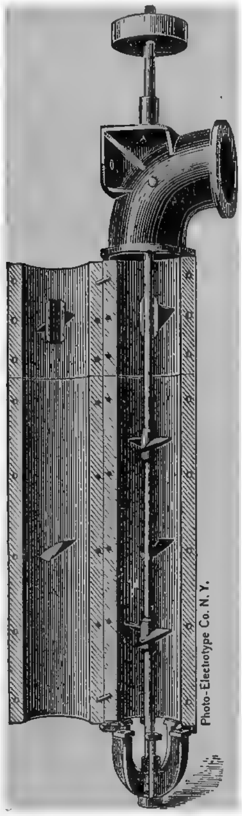

Fig. 75.

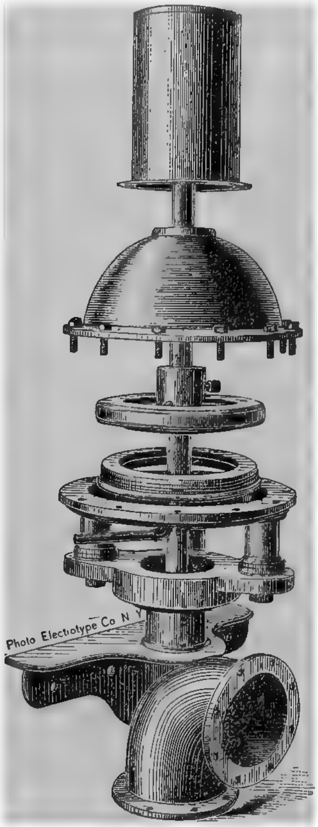

Fig. 76.

attempted, however, to work these pumps under great resistances, a loss from "slip" becomes apparent, especially in some forms, and after they have become worn.

Class C.—DIRECT-CONTACT PUMPS.

To this last general class belong those pumps in which the action of the steam upon the water is direct. There is no reciprocating nor rotary mechanism, and in many of them there are no movable parts at all. From this simplicity result an avoidance of lubrication, and of wear, and also great compactness and ease of repair and renewal of any parts liable to deterioration. The pumps of this class belong to two general groups. The first group includes those in which the lifting action is caused by the condensation of steam in a chamber, while the forcing action is caused by the alternate direct-pressure of steam upon the surface of the water in that chamber. This is somewhat the principle of the very earliest forms of pumping-engines.

Pumps of this class are called pulsometers or aquometers, because of their alternating and pulsating action. A type of one of these is shown by Figs. 77 and 78. There are two pear-shaped chambers, uniting at their converging necks into one steam-inlet pipe, and connected at the bottom by valves to a common suction-pipe from the fluid to be displaced. A similar valve opens to the discharge from the bottom of the chamber, both valves being usually rubber disks, prevented from rising too high by curved guards of brass. There must be a vacuum-chamber on the suction-pipe to relieve the shocks of arrested inlet. It has a small air-check valve, with its stem downward, and similar air-valves are screwed into the neck of each chamber. At the neck-casting is a ball-valve, which oscillates between the mouths of the two chambers, closing them to the access of steam alternately. When in action, steam enters one of the chambers and forces out the contained water until the level of the water falls below the delivery-valve, when steam escapes into the discharge-pipe. This escape causes a partial condensation of the steam in the chamber, and the ball-valve at the neck, obeying a buoyant effort of the water in the other chamber, rolls over to close the orifice of the emptied chamber. Upon the closure of the steam-inlet, the resulting vacuum is at once filled with water forced by atmospheric pressure through the foot-valve, and the cycle would repeat itself for each chamber. The inlets are so proportioned that the chambers shall fill with water more rapidly than they will discharge it. One chamber will be full when the other has discharged about two-thirds of its contents. To start the pump, the steam is admitted to the chambers for an instant and is permitted to condense. Water, of course,

fills both chambers through the suction-pipe, the air-valves remaining closed. When both chambers are full, the steam is again let on, the air-valves are opened a little and the regular working will ensue. The air-valves are

Fig. 77.

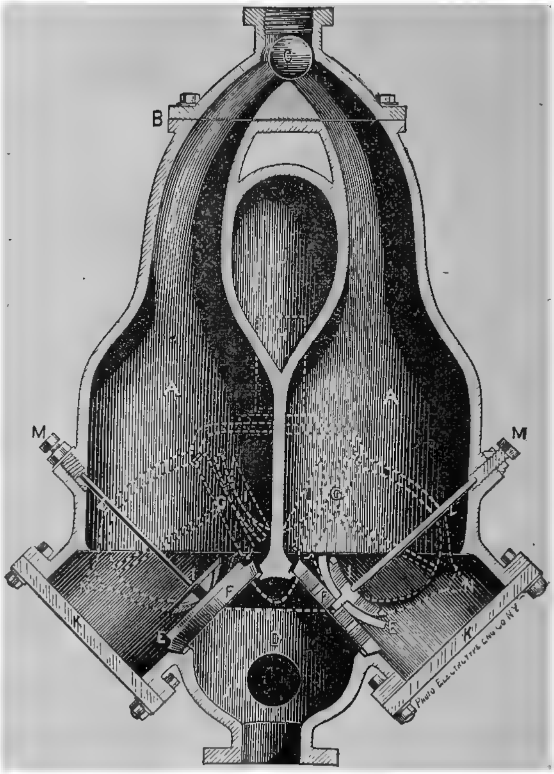

Fig. 78.

controlled by milled neads, to secure the desired amount of opening. Bonnets permit access to the valves, both on the suction and the discharge.

Fig. 79.

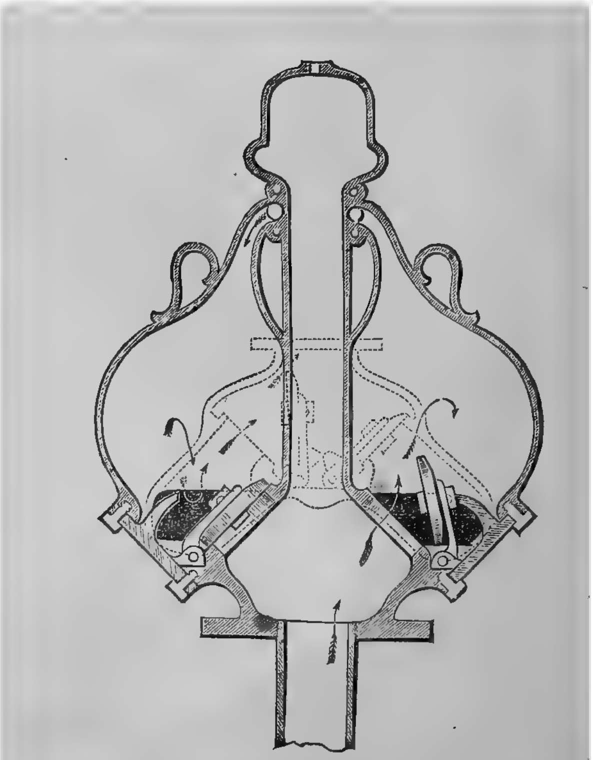

Fig. 80.

Similar in principle is the aquometer, Figs. 79 and 80.

To the second group of pumps of the direct-contact class belong those which depend upon the principle of induced currents. A jet of steam escaping at a high velocity through a small nozzle in the axis of a larger pipe, will act as a species of piston in that pipe, and will aspirate and rarefy the air behind the jet. The current of steam induces the current of air to follow it. Upon this principle depend the steam-jet blowers and exhausters, the vacuum-brake apparatus, and many other devices. For use in pumps, however, the principle is especially applicable, because, beside the simple lifting by the induction of the current and the consequent upward motion of the water in the suction-pipe, a forcing action is possible. When the water lifted up by the pressure of the atmosphere meets the jet of steam, the latter is at once condensed. The living force, however, which was present in the steam still remains in the condensed water, and is competent to force the lifted water forward with a velocity proportional to the original steam-pressure. Hence in pumps of this class there need be no valves even, nor any moving parts, and the delivery will be continuous.

Two devices of this class are shown in Figs. 81 and 82. The steam jet enters from below, the water is sucked

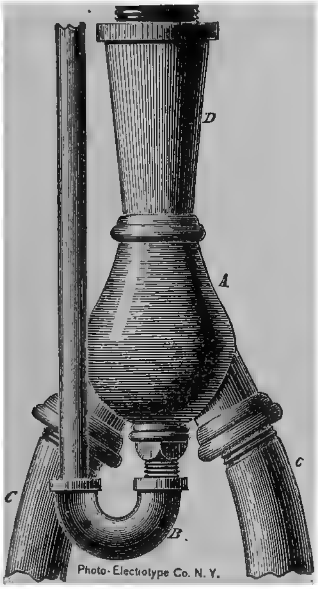

Fig. 81.

Fig. 82.

up through the two orifices below, and they pass together outward, through the outlet upward.

In the pump illustrated by Fig. 83 are typified the various forms of ejector. A jet of steam induces first a

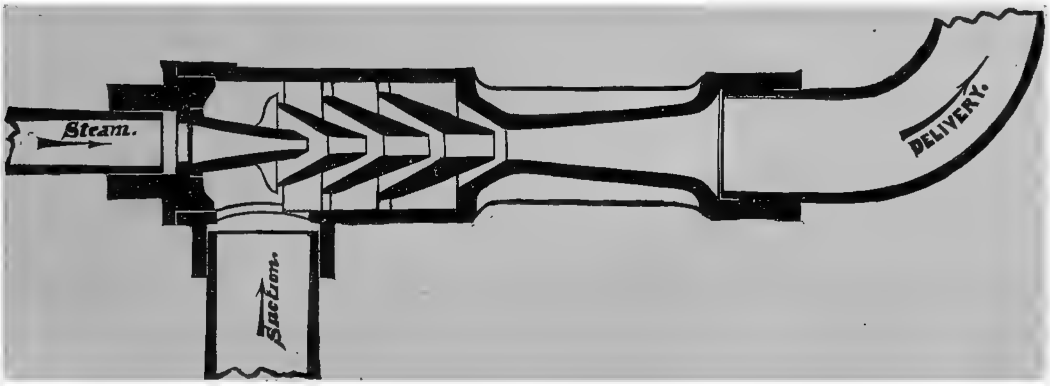

Fig. 83.

current of air, and finally of water. But by the use of several nozzles of an annular construction, the first jet of water is made to induce others, and by this means the living force of a small jet of steam is more thoroughly utilized. Pumps of this class are especially adapted for drainage purposes, where the heating of the discharge-water is no detriment, and gritty solids might damage a pump with moving parts. They are also adapted for an emergency-pump, as they require no foundation nor setting. They need only to be connected at the three outlets by flexible hose, and there is no exhaust to be disposed of.

The class of injectors or inspirators differ in no material respect in their application of the preceding principles. They are designed mostly for boiler-feeding purposes, where they must deliver under a heavy pressure. Hence the delivery-end is reduced in area, and not enlarged as in the type of ejectors. The differences in the various forms are rather in the arrangements looking toward ease of management.

PART II.

PUMPING-ENGINES.

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PUMPING-ENGINES.

As heretofore stated, the distinction between the steam-pump and the pumping-engine is solely due to their difference in size. A large pump becomes a pumping-engine. But as the result of the large amount of water to be displaced, certain details become important, which could be overlooked in the case of the smaller pump.

It becomes necessary, in the first place, to reduce the consumption of fuel to a minimum. Hence the steam must be worked expansively. For a similar reason the engine should be fitted with a condenser and attachments, or even made compound. To secure the greatest economy under varying conditions of speed and load, the expansion must be made variable, and is often in the best practice made automatic.

In the second place, great care must be taken to avoid shocks from the water. The weight and mass of the water increase the inertia to be overcome at every stroke, and any sudden stoppage compels the absorption of living force at some point. If this absorption has to be rapid, a shock will result whose repetition will ultimately loosen joints and wear out the machinery. Hence the valves in the water-chamber must be specially arranged with a view to this, and air-chambers on both suction and delivery sides must be freely introduced. The speed of such pumps, beside, cannot be made very high, for the same reason, and the motion of the water in the forcing column must be uniform.

In the third place, the large volume to be displaced at each stroke makes it necessary that all single-acting plunger-pumps should be vertical. The transverse-flexing strain due to the weight of the plunger at the ends of its stroke would bring excessive wear upon the gland which guides it. Moreover, in pumps of this class, the weight of the plunger is depended upon in part to force the water against the head due to the column. Piston-pumps may be horizontal, inasmuch as the weight of the piston is borne at all times by the bottom of the cylinder, and there may be sufficient bearing-surface to prevent excessive pressure upon each unit of area. The plunger-pump may be horizontal in the double-acting designs where the gland is in the middle of the two water-chambers, or in pumps of short stroke.

1.—NON-ROTATIVE PUMPS.

Pumping-engines may be grouped under two classes, the rotative and the non-rotative, according as they attain the expansive working of the steam by means of a fly-wheel or not. To the non-rotative class belong the vertical Cornish pumping-engines, the horizontal Worthington engines, and the other engines of the direct-acting type. To the rotative class belong the Holly and Leavitt engines, and all the horizontal engines which use the living force of the fly-wheel.

The Cornish pumping-engine is essentially a vertical one. The weight of the plunger is made sufficient to displace the water against the head, and the work of the steam is only that necessary to lift the weight of plunger and rods. The original Cornish engine was a beam-engine, the plug or master-rod passing down the pumping-shaft from the outer end of the beam. For water-works purposes there are but few beam-engines, the side lever being used in one or two cases. The direct-acting or Bull-Cornish engine is the type which has been preferred. In this type the steam-cylinder is supported upon transverse beams directly over the plunger and pump-barrel, which are immersed in the well. The mass of the rod is so calculated that steam admitted below the piston and cut off at an early point shall be just adequate rapidly to lift the plunger and fill the barrel, without endangering the upper cylinder-head. When the piston is at the top of its stroke, the equilibrium-valve is opened, which establishes a connection between the top and the bottom of the cylinder, so that the piston and plunger may sink gradually and displace the expanded steam into the volume above the piston and the water in the barrel into the forcing main. When the lower end of the stroke is reached, the equilibrium-valve is closed, the admission-valve is opened below

the piston, and the valve to the condenser is opened above it, so that the cycle may repeat itself. It is possible by means of the "cataract" to cause any desired interval between the strokes. The rod opening the admission-valve may be the prolongation of a piston-rod from a small cylinder. If this small piston be lifted on the descending stroke of the pump, the cylinder may fill with water by aspiration through a check-valve. The small piston, which is weighted, can therefore descend only as the escape of the aspirated water will permit, and the speed of this escape can be controlled by the greater or less opening of a small cock in the bottom of the cylinder. Hence for variable or intermittent service, it is possible to have a very small number of strokes per minute.

In this system it is the mass of the plunger-rod and piston which intervenes between the variable force of the expanding steam and the constant resistance of the water-column. But as the motion is not continuous, there must be special devices of buffers to prevent overstroke. The boiler-pressure must also be kept uniform, or else careful regulation of the throttle-valve is made necessary. Then inasmuch as it is the resistance of the water-column which retards the rapid fall of the plunger, any failure of the foot-valve either to open or to close will permit the great weight of the reciprocating parts to come down with high velocity, perhaps knocking out the bottoms of both cylinders and demanding extensive repairs. The danger of the latter accident has been diminished on the Bull engine at Erie, Pennsylvania, by a device of the engineer in charge. The rod cannot move enough to open the equilibrium-valve unless the full resistance is upon the pump-barrel. A small cylinder connected by a pipe to the pump-barrel moves suitable catches which only release the valve-rod when the little cylinder is full of water, and this latter can only occur when the pump-barrel is full and the foot-valve is closed, and the motion of the plunger has begun to displace the water upward. The little cylinder empties of course upon the up-stroke of the plunger, and sets the catches anew. This, however, will not prevent accident to the pump in case of the bursting of the rising main nor in case of the failure of the eduction valve. The valves of the Cornish engine are usually opened by tappets upon rods which move with the plunger. They are held open by catches, which are in turn released by other tappets. Upon the front of the cylinder are two rock-shafts, one of which carries the levers for the admission and exhaust, and the other carries the gear for the equilibrium valve. Each shaft carries the catches for the other, to hold the valves open during the proper interval. The valves are closed by weights when released, which fall into dash-pots below.

The Cornish system has given what were considered at the time very economical results. The high expansion, varying velocity, and moderate driving of these engines have enabled them to show a high duty in some cases. But there are great drawbacks to the system. The flow is not uniform in the forcing main, the liability to accident is great, they are costly to build and to erect foundations for, and their duty has been exceeded by other types. The number erected for large pumping-works has been growing less and less every year.

The other class of the non-rotative pumping-engines includes those designs which are simply large direct-acting steam-pumps, with the slide-valve thrown by steam or else working upon the duplex system. They are made either non-condensing, condensing, or compound, according to the magnitude of the service for which they are employed, in order that a suitable relation may be maintained between the interest account and the coal account in any enterprise. Most of the leading builders of steam-pumps have several pumping-engines in service, but the duplex system devised by the late Mr. Henry R. Worthington is the most widely extended. This pump is met with in five forms. As an auxiliary or spare engine, and for small and intermittent service, a high-pressure, non-condensing engine, working without expansion, has been introduced. It works upon the duplex system, but cannot be depended upon for a duty higher than twenty million. The second form is also non-condensing, but works with a certain degree of expansion, and gives a duty of thirty or thirty-five million. The expansion in each complete pump takes place in two cylinders.

The third form includes the condensing but non-expanding engines, using but one steam-cylinder upon each rod. The fourth form includes the compound engines with receiver. There is a small high-pressure cylinder upon one rod, and a large condensing cylinder upon the other. The steam exhausts from the small cylinder into a receiver or tank of cast-iron or boiler-plate, having a capacity of eight or ten times that of the cylinder. From this receiver the larger cylinder takes its supply. By carefully proportioning the areas of the two cylinders to the work to be done, a uniform propelling energy is retained upon both. There is no expansion attempted in the small cylinder, the expansion being effected by the differences of area in the two cylinders. The fifth form includes the four-cylinder, expanding and condensing compound engines of the largest type. The steam-valves are balanced by being hung from a hinge-joint in the top of a dome upon the valve-chest, with ring-packing to avoid the difficulty of the motion in the direction of the versed sine. The condenser and air-pumps are in a well below the axis of the cylinders, moved by a bell-crank and link from a cross-head. The steam-valves are moved by a contact-joint permitting a little lost motion at the end of the valve-stem. This latter is continuous for each pair, the steam-passages being made longer for the smaller cylinder. The arrangement of the plunger is a special feature. It is hollow and air-tight and slides through an inelastic ring of some depth, fitted in the partition which divides the water-chamber. The valves are made of small diameter and are close to the barrel. Pumps of this class will give an average duty of sixty-five million.

Other makers have also put pumps of the duplex type upon the market within a recent date. The advantages of the direct-acting duplex system are its compactness, and, therefore, cheapness of foundation; the strains are

distributed so that the engine is self-contained; the ease of their motion, the direct application of power, their freedom from shock, their certainty of action, and the reduction to a minimum of the momentum of the moving parts. This latter feature secures an immunity from accident in case of breakage, or failure of valves. The Corliss pumping-engine at Providence is also of this class, or is rather a sextuplex engine. Six steam-cylinders disposed on radii round a circle cause a central vertical crank-shaft slowly to revolve. There is no fly-wheel, the speed is controlled by the resistance of the water, and every stroke is of definite length. The water-cylinders are upon radii intermediate between the steam-cylinders, and are worked from the same crank.

2.—ROTATIVE PUMPS.

To the rotative class of pumping-engines belong those in which the living force of a rotating fly-wheel gives out to the pumps during the latter part of a stroke the work stored up before expansion began. Since this rotation of the fly-wheel is caused by a crank, the stroke of piston and plunger must be of definite length, and one element of danger in the Cornish system is thus avoided. But the momentum of the fly-wheel may cause special dangers of its own, inasmuch as the water-plunger may be made to crash resistlessly against an obstruction which would arrest the Cornish or direct-acting plunger, without accident. Moreover, the varying velocity of the plunger and column as driven by a uniformly revolving crank brings strains upon the mains when the velocity is accelerated during the first half of a stroke. The interval also for the closing of water-valves is quite short, causing them sometimes to slam against their seats instead of seating quietly.

In spite of these drawbacks, the crank and fly-wheel pumping-engine is in very general use. It appears in six forms. The first is the horizontal piston pumping-engine, and the second is the inclined engine. These are connected directly to the crank, and the steam- and water-cylinders are upon one line. The third form is the bell-crank engine, where the pumps are vertical in the well, and the steam-cylinders are horizontal. The fourth form is the beam engine, with cylinders vertical, and the beam overhead or below. To this class also belong the side-lever engines. The fifth form includes the few vertical engines directly connected, with two fly-wheels outside the frame. The sixth form includes the types of geared engines, where the pumps and steam-engines may be of different designs.

To the first type of the horizontal engines belong the several engines which are but large specimens of fly-wheel pumps. These have been erected by several designers of these specialties, and illustrations may be seen at Nashville, Tennessee, and at Covington, Kentucky. The larger engines of the horizontal type would be exemplified by that of Grand Rapids, Michigan. The engine is condensing, the steam being distributed to the cylinder by four poppet-valves. The air-pump is at the side of the bed-plate, being worked by a rock-shaft below, and an arm from the cross-head. The arm under the connecting-rod is of the U-shape, so universal in inclined ferry-boat engines. The steam- and water-pistons are keyed into a cross-head between the two cylinders. The water-valves in horizontal pumps are either disk-valves or else clack-valves, seating upon inclined gratings. The Corliss Pawtucket engine uses the Corliss valve upon both the high and low pressure cylinders.

A very prevalent type of the inclined engine is shown by the Holly engine. Four steam-cylinders are connected to one fly-wheel shaft, one pair being connected to one pin upon the wrist-plate. These pins are arranged quartering so as to give a regular flow of water, the two upon each side again being bolted to the bed-frame so as to be at 90° with each other. The steam connections are such that the engine can be run as a four-cylinder condensing engine or as a compound engine, expanding in any desired number of cylinders, and condensing in the last only. The piston-rods are keyed into a sleeve, so that any of the four pumps may be disconnected upon occasion. The steam is distributed by slide-valves, but the degree of cut-off is determined by a poppet-valve on the back of each cylinder, which is opened by a cam. The length of admission through this poppet-valve is determined by the position of the cam upon the shaft which revolves it. The cam is of the well-known form which is of different lengths of face at different parts of its length. The shorter the face under the valve-lever the shorter will be the period of admission, and the position of the cam on its axis is determined by the device called the regulator. This consists essentially of a weighted piston connected by small pipe with the forcing-main. The motion of this piston is carried to a pair of bevel-friction cones, which is caused to move endwise upon a spline, and effects contact with a third friction-cone on an axis at right angles to that of the other pair and between them. It will be seen at once that if these first cones be made to revolve, they will turn the third in one direction or the other according as it is engaged with number one or number two. It is a very simple problem to cause the positive or the negative motion of the third wheel, caused by rise or fall of the properly weighted piston, to produce a later or earlier cut-off of the admission of steam, and maintain a uniform pressure in the mains, by adjusting the position axially of the lifting-cams. There are, of course, objections to the expansion of the steam inside the valve-chest, but it is a very simple method of securing regularity.

Another inclined engine is the Shield engine of Cincinnati. The steam and exhaust valves are of the poppet-type, the former being worked by lifters moved by an especial cam upon the fly-wheel shaft, playing in a yoke at the end of the hook-rod. This secures an early and prompt cut-off. The pumps are vertical and below the fly-wheel shaft.

There are several types of the third form or bell-crank engine in use in Pennsylvania. A pair of cylinders is upon one rod which is connected by short connecting links to the upper end of a large right-angled isosceles triangle. To the other end of the hypothenuse are attached the pumps, down in the well. The triangle which makes the bell-crank is pivoted at the apex, and the fly-wheel is carried upon the horizontal bed-plate. This type has not been very largely duplicated.

The fourth form includes most of the largest and most successful engines of the day. The pumps are vertical, and the steam-cylinders, vertical or slightly inclined, are connected to the crank-shaft and to the pumps through a beam. In the greatest number the beam is overhead, supported either upon the open frame or upon a hollow pillar, which also serves for air-chamber. In the earlier engines (Chicago North Side, and New Bedford for example), the engine is a simple beam-condensing engine, resembling very much the type still in use for propelling river and coast steamboats on the Atlantic waters. The cylinder-valves are of the poppet-type, working in two chests connected by side pipes. The valves are lifted by toes from lifters on a rock-shaft or by rotating cams. The steam-rods usually have an adjustable cut-off gear of the Stevens or the Sickles type, by which the rods are let fall when a latch is released by the action of an adjustable wedge. The blow of the falling weight is cushioned by a dash-pot. The cut-off, when revolving cams are used, is effected by causing the cams to bear upon a block of varying profile, instead of lifting the toes directly. By moving this intermediate block the steam-valve may be kept open a longer or a shorter time. Often the steam-rod carries a bracket with a screw at the end, which may be caused to rest upon a similar bracket on the exhaust-rod. While the latter rod is up the steam-valve cannot be closed entirely. The water-pumps are either below the steam-cylinder, directly connected, or else are worked from the beam, one being placed upon each side of the beam-pedestal. In the later engines the cylinders are compounded, by which the duty of the engines has been increased, and the pressure upon the beam and crank made more uniform. At Chicago West-side station, the valves are of the Corliss type and arrangement, worked from a wrist-plate. The release is effected by throwing out of gear a jaw-clutch on the valve-stem. The engine is started by working the wrist-plate by a small steam-cylinder. In the Leavitt engines, at Lynn and at Lawrence, the two cylinders are inclined to the perpendicular, and take hold of the beam on opposite sides of its center. The valves are gridiron slides moved by cams which have graduated faces, and their position axially on the cam-shaft is determined automatically by a governor. The pump is of the bucket-plunger type. A beam-engine with the beam below the cylinder, is illustrated by the Scowden engines of Cincinnati. The pumps are below the cylinders, and the fly-wheel shaft is at the floor-level. The peculiarity of these engines lies in the connection of the two engines by a drag-link between two wrist-plates.

The fifth form includes those vertical engines where there is no beam. The pumps are below the cylinders, the fly-wheel being turned by pins upon the spokes through connecting-rods from a cross-head between the cylinders. There are two engines of this type also at Cincinnati. The valves are poppet-valves, worked from a rock-shaft by lifters and toes.

Under the sixth form may be included the various types of geared engines. Upon the fly-wheel shaft of the steam-engine is put a pinion which meshes into a large gear upon the shaft which is the crank-shaft of the pumps. By this means is secured the necessary slow motion of the pumps without compelling an equally slow motion of the steam-piston. Hence a smaller steam-cylinder can be used, and the internal condensation and re-evaporation may be less, inasmuch as the radiating surface is reduced, and the number of revolutions is increased. The steam-engine also can work more expansively, since its weakest time does not always come when the resistance is greatest, compelling in this latter case a heavy fly-wheel. There are several illustrations of these geared engines at various places. At Hartford there is an automatic cut-off condensing beam-engine, driving four plungers, and at Providence there is the Nagle engine, which is a vertical direct-acting engine with disengaging valve-gear, driving horizontal pumps. There would seem to be great advantages in this type of engine, but their reported duty has been exceeded by compound engines of the fourth form.

The present condition of the pumping-engine problem is a very hopeful one. The duties of previous experience have been far exceeded, and builders are able to furnish engines under a guarantee. In many cases it is simply a question of financial policy, whether a cheaper and less economical engine will not cost more than a compound beam-engine with its economy of fuel, but its greater first cost and outlay for foundations and buildings. This question can only be answered in any given case by a thorough investigation of all the conditions which enter into the problem.

PART III.

STEAM FIRE-ENGINES.

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The steam fire-engine is a pumping-engine which presents several peculiarities. It must be combined with a boiler and must be self-contained. It must be capable of being driven to its highest capacity without giving out. It must be as light as is consistent with the condition of strength, so as to be easily propelled to the scene of the emergency and must adjust itself to variations of level of road-bed and of position. The boiler must be a rapid steamer and capable of using very poor waters. The pump must be able to suck water from deep cisterns and force it through long lengths of hose to a considerable height. The running-gear must be such as to make the engine manageable upon the road and yet not too unstable when at work. The essential parts, therefore, of the steam fire-engine are the frame and running and propelling gear, the boiler, and the pump and attachments. There must be certain features common to all the designs, but there is a considerable variation in the details. Engines are made of different sizes and capacities, being known as engines of the first, second, third, or fourth

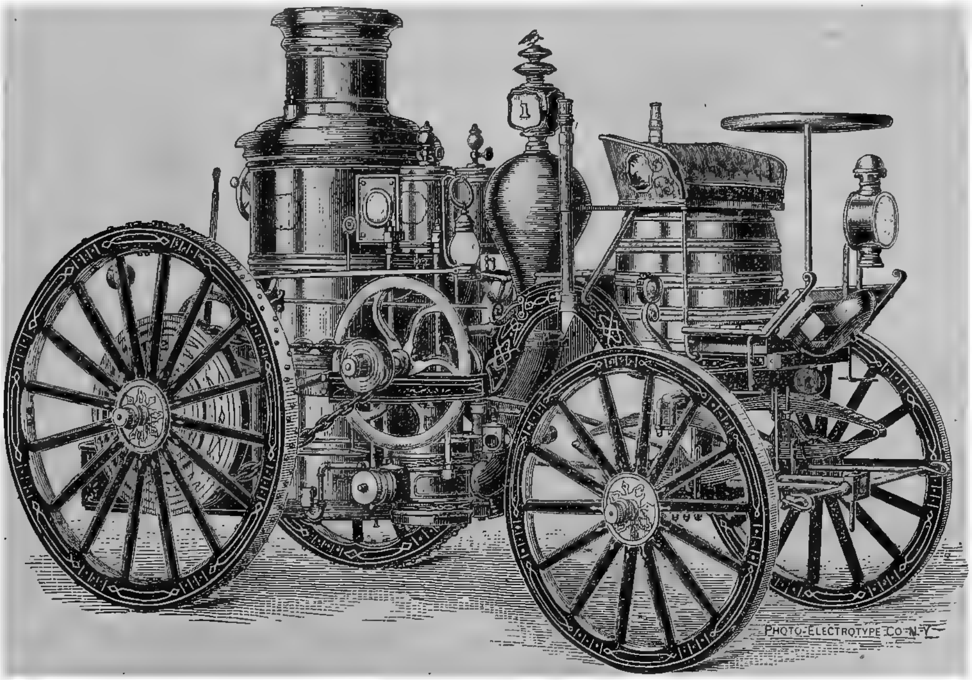


Fig. 84.—Amoskeag self-propeller.

class. There is unfortunately a lack of uniformity in the classification by different builders. The smaller sizes are often made to be drawn by hand, the larger ones being adapted for horse-traction, single or double, and there are a number of self-propellers in service, where horses are dispensed with.

The running gear consists of four wheels, made either entirely of iron or preferably of wood and iron combined. The front wheels under the driver's seat support the seat and the front end of the frame, either through two elliptical wagon-springs, through two locomotive springs, or else through a spiral spring in the center. In the former case the two springs, permit a sidewise inequality of the ground to be taken up in the flexible connection to the frame. In the second method it is judicious to make a horizontal pin-joint between the axle and the spring-case casting, so

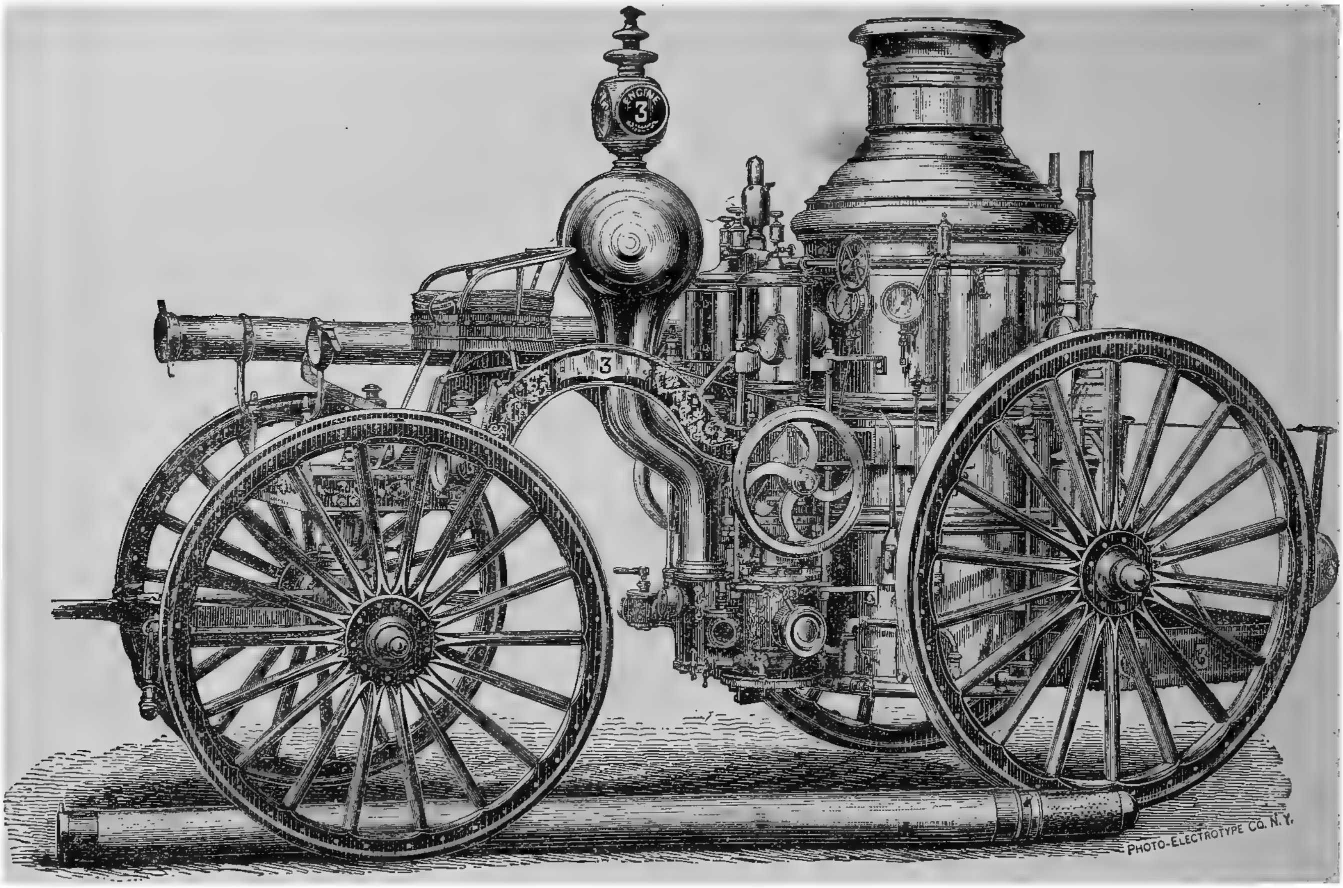


Fig. 85.—Gould engine.

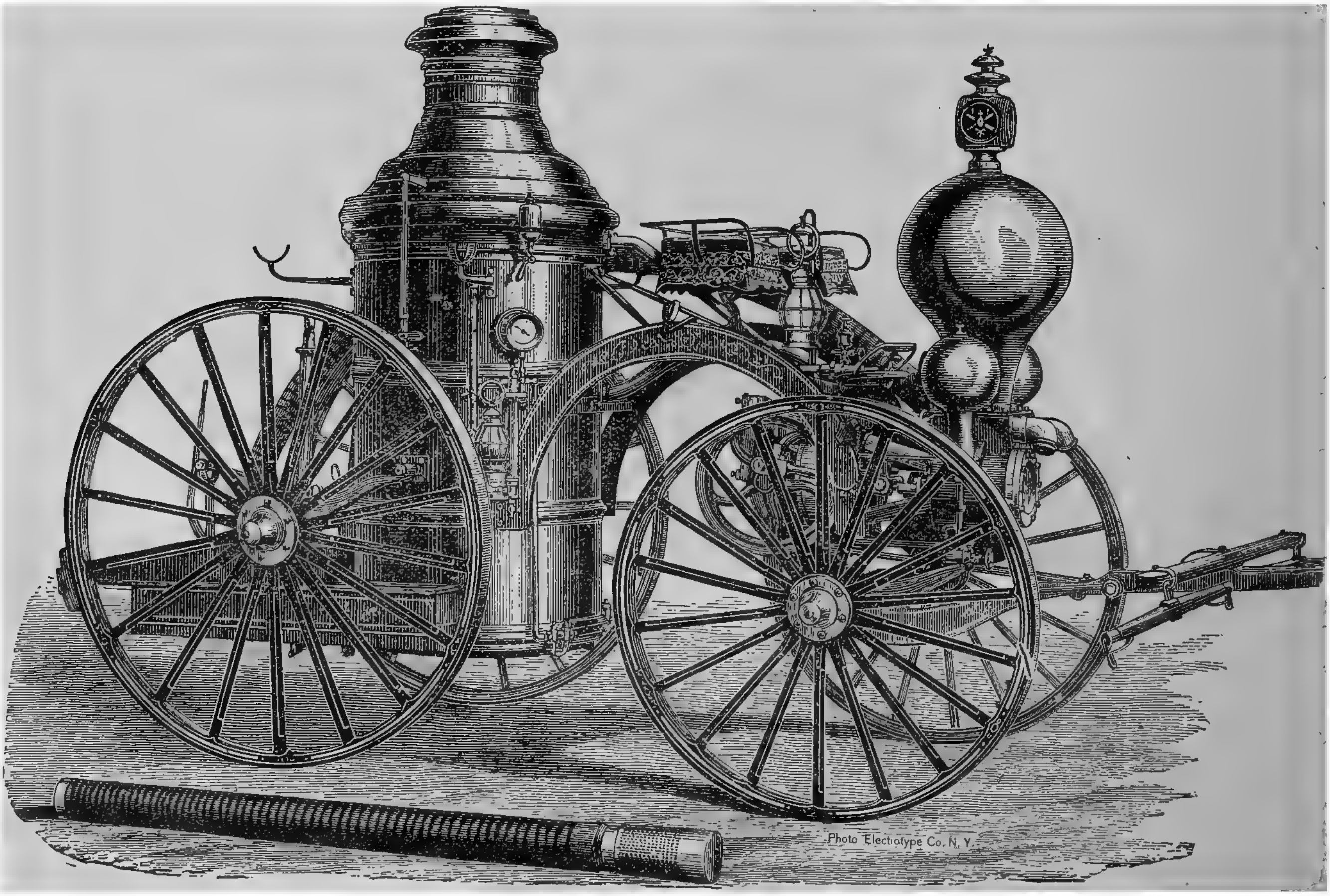


Fig. 86.—Button engine.

as to prevent the wrenching of the frame when one wheel falls in a hole. The same end is attained by hanging the front end from a locomotive spring across the engine by links from the axle.

The frame is made of forged iron about four inches deep, in many designs forming the foot-plate brackets of the driver's seat. The frame is made either "straight" behind the seat or else is curved into the "crane-neck"

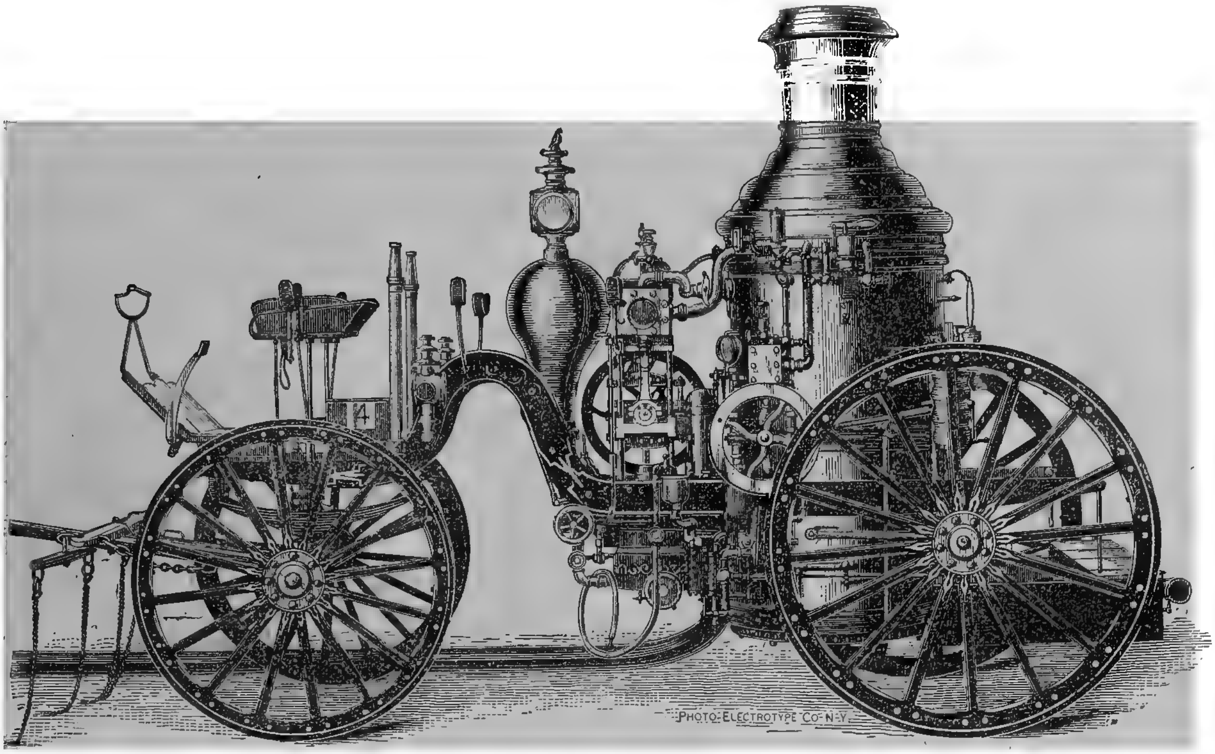


Fig. 87.—Ahrens engine.

form. The advantage of the latter shape is that the fore-wheels can turn under and permit a short curve to be turned. In one of the forms of engine the frame bolts down to the pump sole-plate behind the fore-wheels, and is

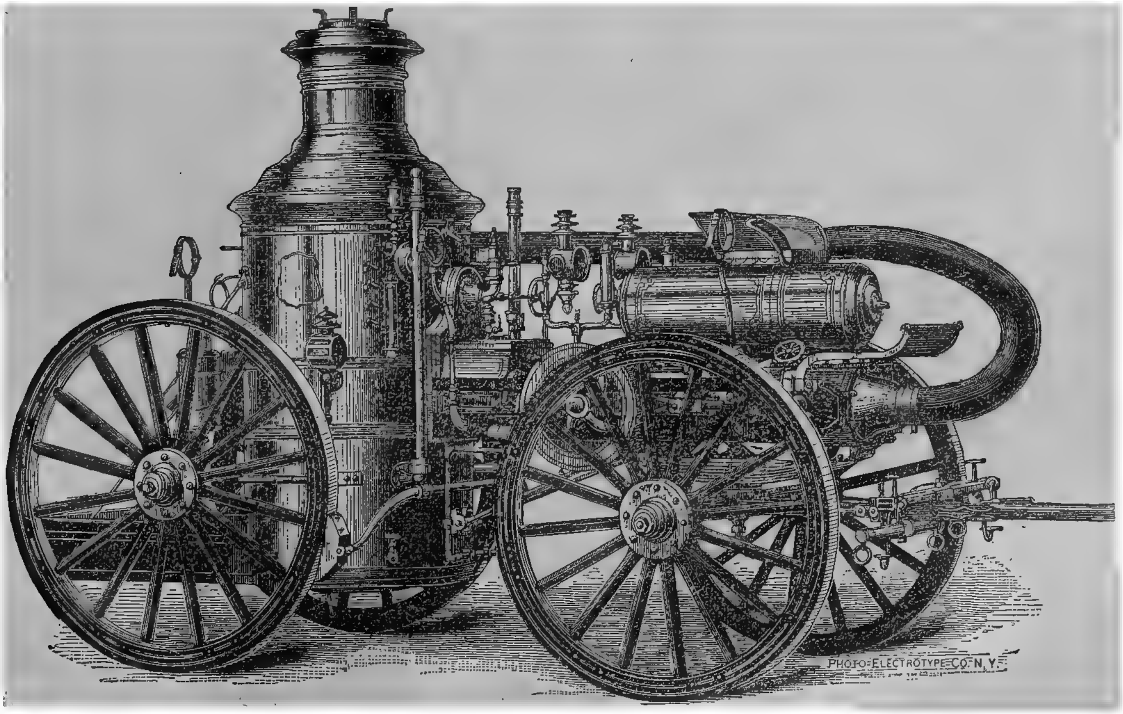


Fig. 88.—Clapp & Jones engine.

so shaped as to permit the wheels to clear. The angular crane-necks are made by welding up flat metal into the required profile. One form of round neck is made from the solid without welds. The rear end of the frame is often bolted directly to the shell of the boiler, and the rear axle, bent to encircle the latter, supports it by links

from a locomotive spring upon each side. Another arrangement is to curve the frame around the boiler and to hang the latter to the axle by stout spiral or rubber springs. In the case of self-propellers the rear axle has to be straight and continuous and passes across the frame behind the boiler. The propelling gear consists in an endless

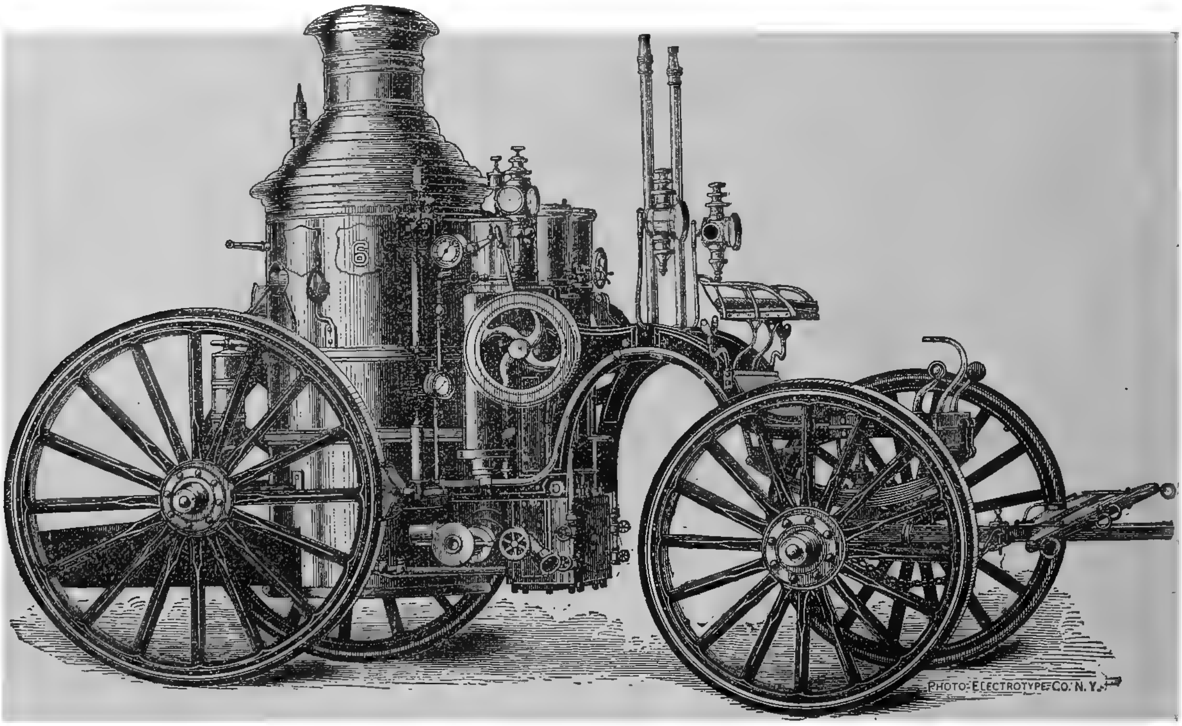


Fig. 89.—Clapp & Jones engine.

chain connecting the fly-wheel shaft of the pumps with the rear driving-axle. The chain passes over a grooved sprocket-wheel on the fly-wheel shaft which is secured to the latter by a removable spring key. The removal of this key permits the fly-wheel shaft to revolve for pumping without driving the propelling axle. The face of the large grooved pulley on the rear axle is similarly recessed for the chain, but is loose upon the axle as also is the traction-

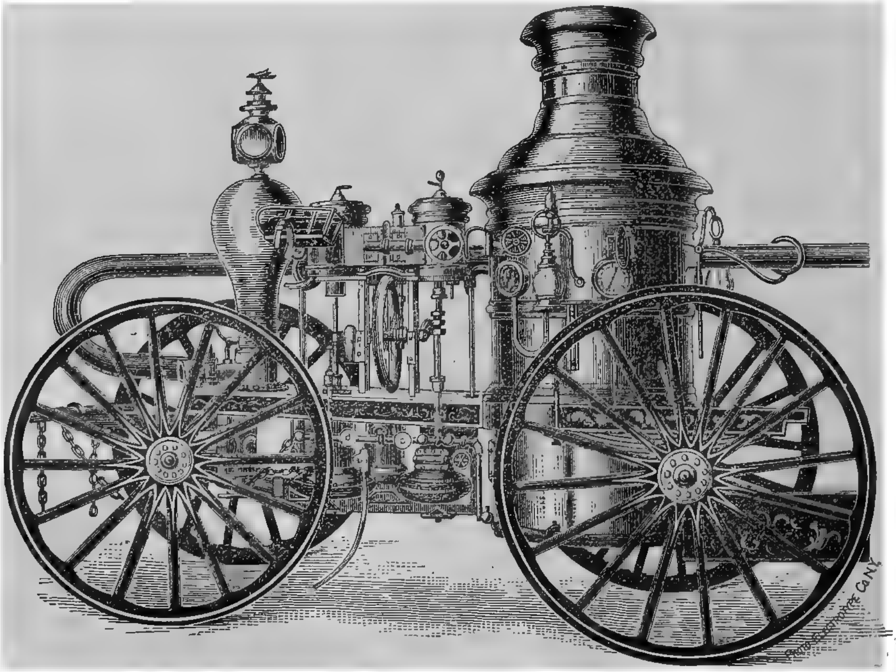


Fig. 90—Cole engine.

wheel upon the same side. The reason for making one wheel fast on the axle and the other loose, is to enable one wheel to move farther than the other in going around curves and in turning. The chain-pulley has a pair of bevel-wheels (whose axes coincide with a diameter of the pulley) upon the circumference of an inner concentric circle. These bevel-wheels engage into a bevel-wheel upon each side of the pulley. One is fast to the loose traction-

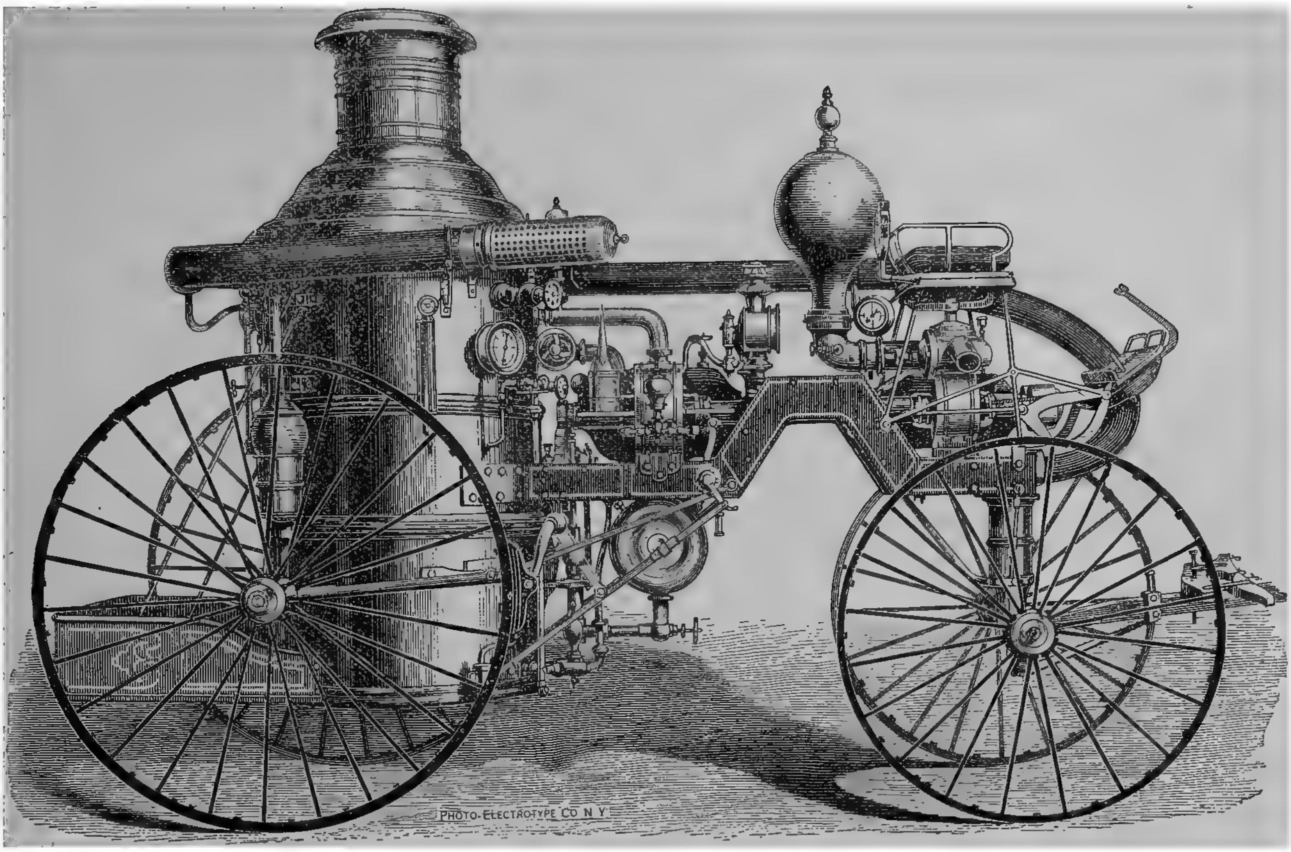


Fig. 91.—Silsby engine.

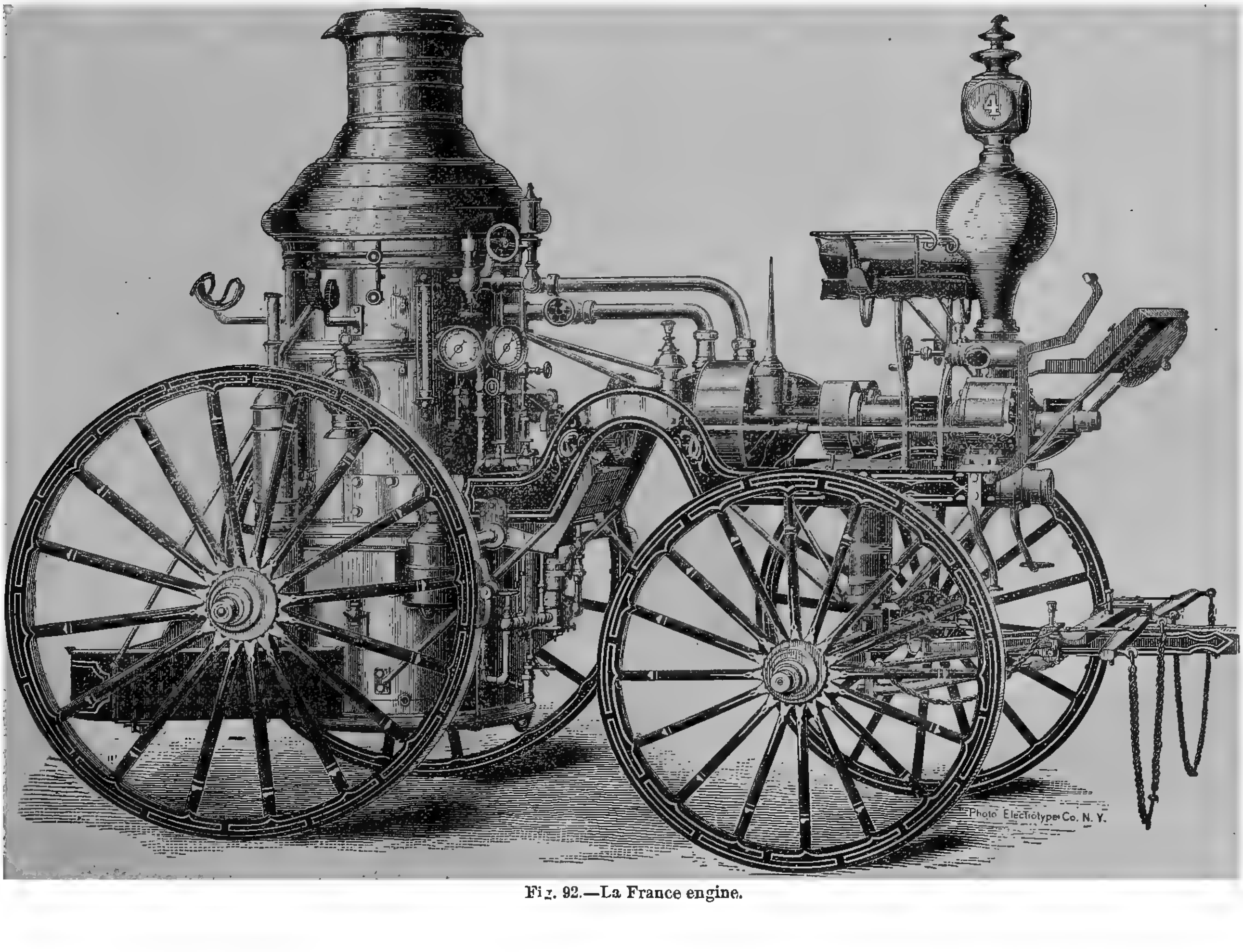


Fig. 92.—La France engine.

wheel on the outside, and the other is fast to the driving-axle on the inside and therefore to the other traction-wheel. If the resistance offered by the two wheels is the same they will turn together. If the resistance is unequal the gears on the pulley will roll upon the gear fast to the most resisting wheel and permit the slip of that wheel while the other is driven. To permit the brakes upon the rear wheels to bear equally on both, even if they

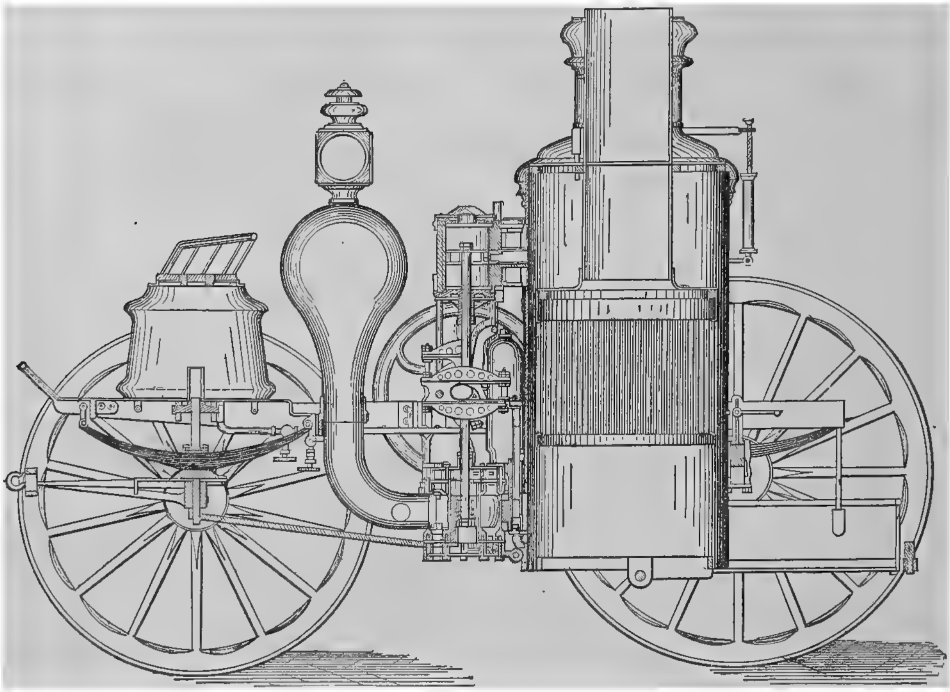


Fig. 93.—Section of Amoskeag engine.

are not traveling on level ground, an excellent practice is to put the shoes on separate beams, connecting them to the foot-lever by an equalizer. The steering gear upon self-propellers is by a hand-wheel in the front foot-plate,

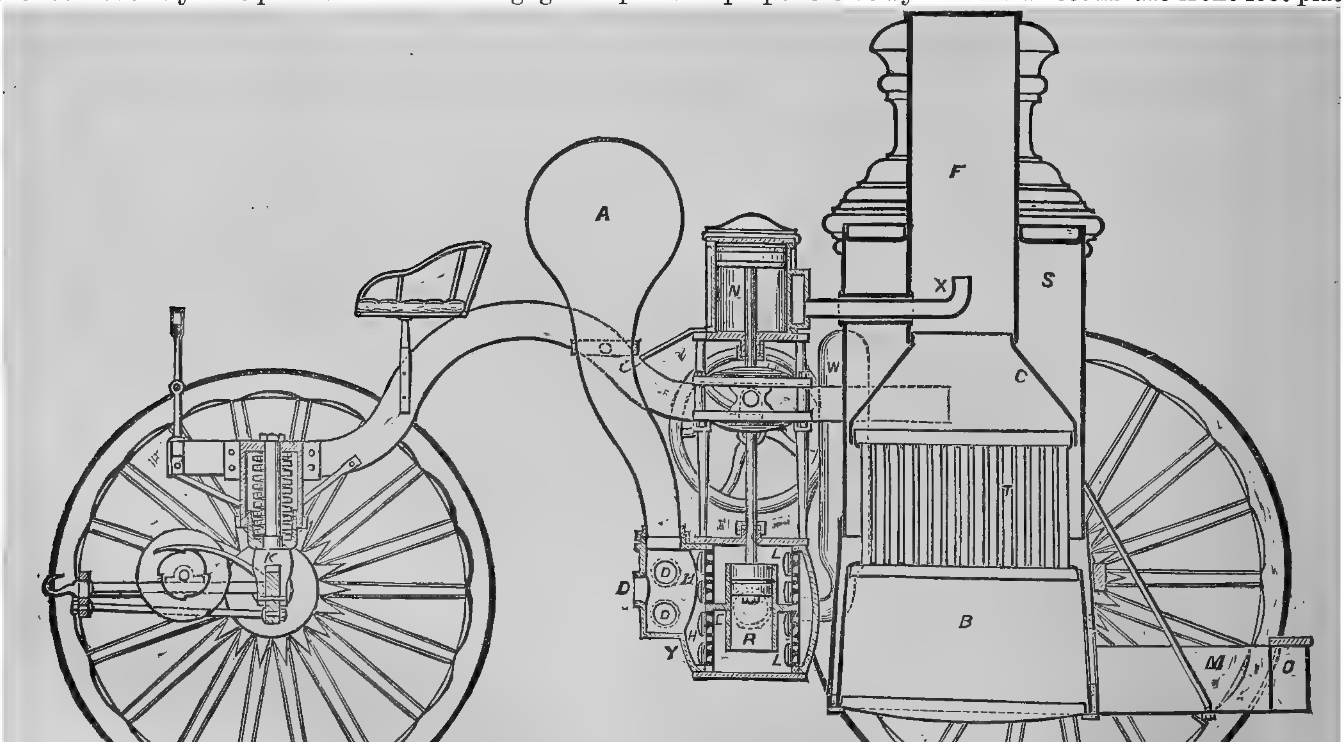


Fig. 94.—Section of Gould engine.

which turns a small pinion meshing into a sector forming part of the fifth-wheel gear. The engines are fitted with a link-motion for reversing the direction of the travel of the engine. This self-propelling gear is applied only to the larger engines with two pumps.

The fire-engine boiler must be specially designed for making steam rapidly. The boiler must be small so as to be easily carried, and yet there must be a large heating surface thoroughly utilized. The boiler is universally of the upright tubular type, the older practice approving fire-tubes of brass very close together, and all submerged. The submergence keeps a uniform tube temperature and lessens the dangers of leakage and accidents from unequal contraction and expansion. The chimney passes through the steam space, and acts as a drier and superheater. Newer practice prefers the water-tube in addition to the fire-tube. The Latta boiler of the Ahrens company, the Field-tubes of the Silsby company, and the La France boiler, are types of these designs. The rapid circulation

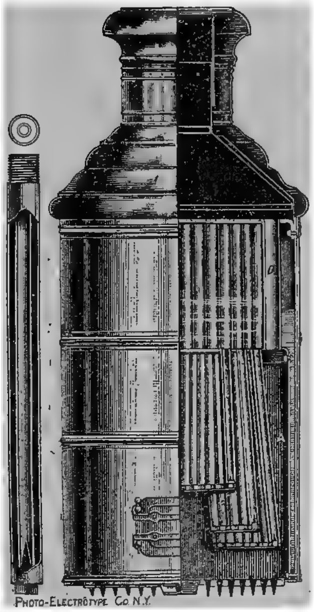


Fig. 95.—Silsby boiler, with Field-tubes.

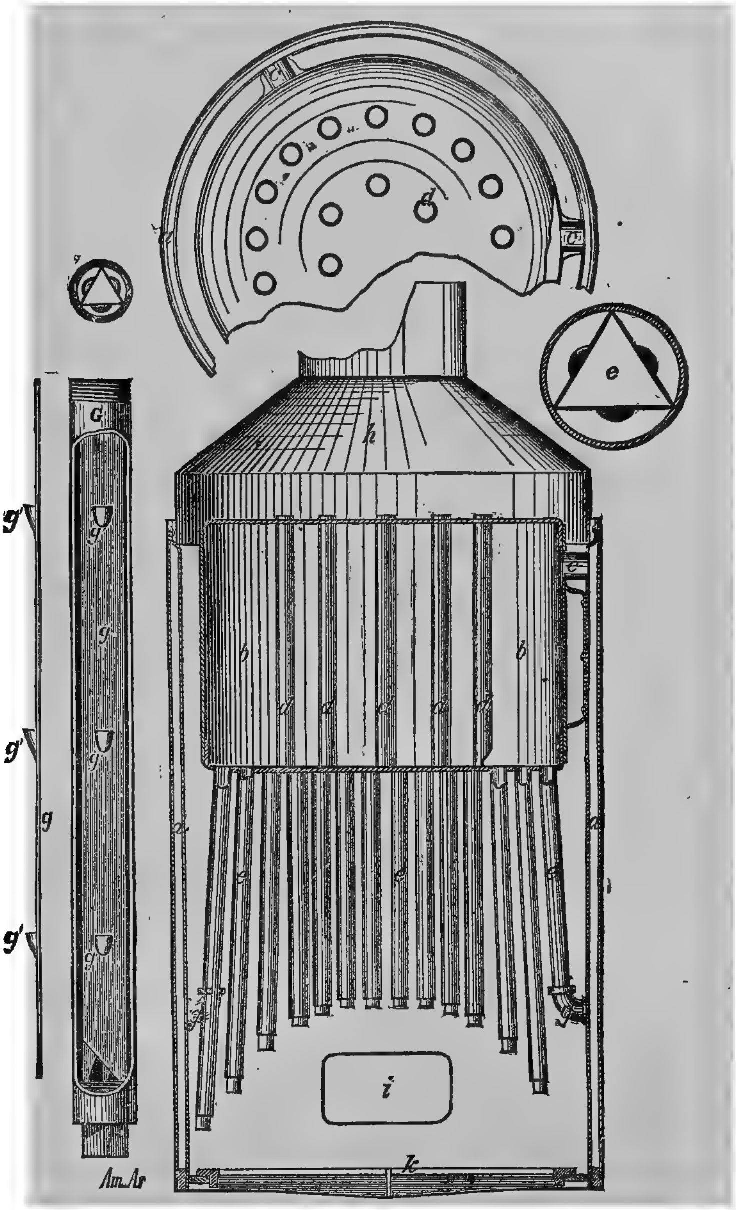


Fig. 96.—Clapp & Jones boiler.

in the water-tubes prevents the adherence of scale to them, and they cannot lose their efficiency by becoming covered with soot and ashes. In the La France boiler is a special trough or ring for catching the sediment carried into it by the currents of convection. Many of these water-tube boilers diminish the number of the fire-tubes, retaining only enough for the draft, and having them only partially submerged, as in the stationary upright boiler. The blast is furnished by the exhaust from the engine or else by special jet or blower in the stack. The exhaust-pipe terminates in a number of nozzles under the petticoat-pipe, which nozzles can be more or less closed by conical plugs. The position of these plugs can be controlled from without, and the velocity of the jets made variable. The boilers work usually under steam from eighty pounds up to about locomotive pressure, and are lagged. Wooden strips are covered with a sheathing of Russia sheet-iron, and the whole is banded by brass rings. The smoke-box trimmings are usually also of brass.

For pumping there are three general classes of engine. The first class contains the few where the valves are steam-thrown, as in the direct-acting pump. The second class includes the fly-wheel pumps, which can be again

separated into the connecting-rod engines and the yoke-engines. The third class includes the rotary-engines and pumps. There are either one or two reciprocating pumps, according to the size of the engine, arranged side by side

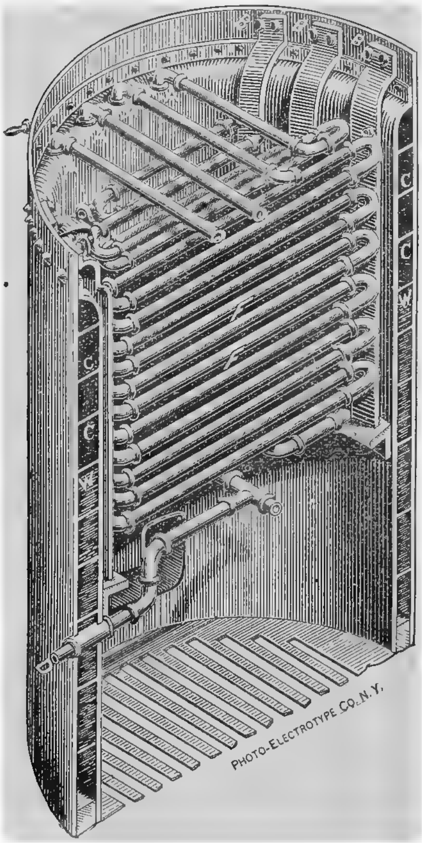


Fig. 97.—Latta boiler.

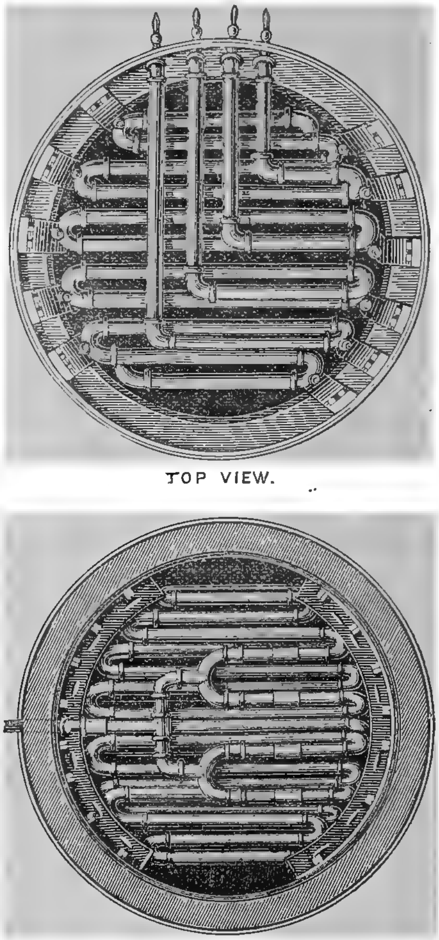


Fig. 98.—Latta boiler.

against the front of the boiler. One builder puts one in front of the other, to avoid the tendency to lurch when only one of the two is in the service. Using high pressures, the locomotive type of piston-packing is very

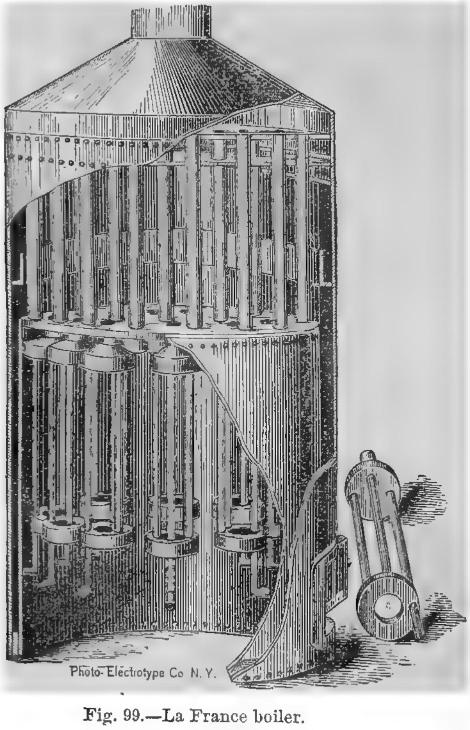
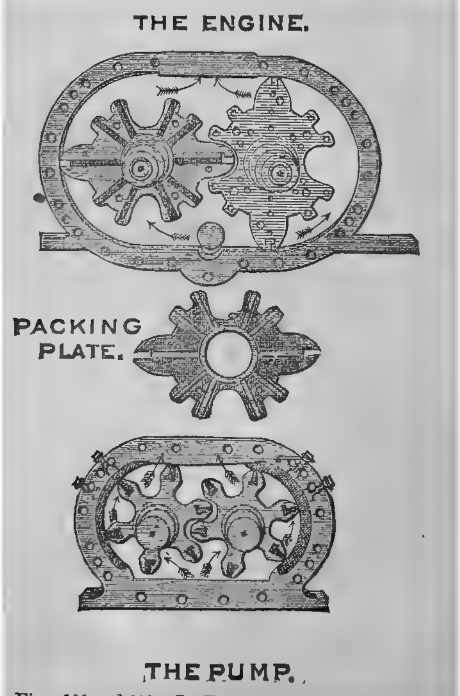


Fig. 99.—La France boiler.



Figs. 100 and 101.—La France engine and pump.

usual. There are not very many steam-thrown valve-gears in service. It is not popular because no cause can be allowed to result in a failure to start immediately, in such pumps as these. There is one form of connecting-rod engines where the cylinders are horizontal, but the vertical arrangement, driving the cranks of the fly-wheel shaft by a yoke and slide-block is much more usual. The same shaft is prolonged at one side to carry the chain-pulley in the self-propellers. The pump-barrels are below the steam-cylinders, and are usually piston-cylinders. The valves are commonly rubber disks, and in some designs are so arranged as to be all on one plate, which is easily removable. The bore of the pump is often made of brass and removable. Cup-leather packing is popular for the pistons.

There are two builders making rotary pumps and engines exclusively. The advantages of both rotary engine and pump are their freedom from valves, their high speed and capacity, and their compactness. There is also no reversing of the water-currents at a high speed. They are not popular for certain services, inasmuch as increasing

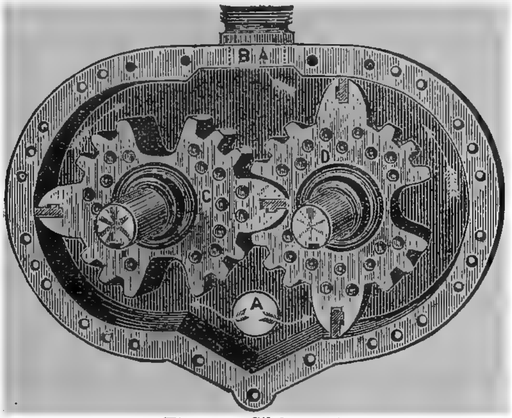


Fig. 102.—Silsby engine.

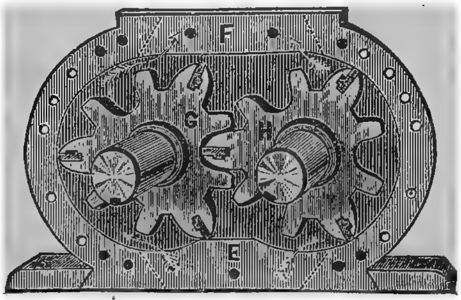


Fig. 103.—Silsby pump.

resistances will diminish the delivery from the nozzles, especially after hard service has worn the contact-surfaces. The rotary engine, moreover, is not economical of steam, as it permits little or no expansive working. They are, however, very largely in use for town and village protection.

Figs. 84 to 92 show the various forms of the steam fire-engine.

Fig. 84 is the Amoskeag self-propeller (page 51).

Fig. 85 is the Gould engine (page 52).

Fig. 86 is the Button engine (page 52).

Fig. 87 is the Ahrens engine (page 53).

Figs. 88 and 89 are the Clapp & Jones engine (pages 53, 54).

Fig. 90 is the Cole engine (page 54).

Fig. 91 is the Silsby engine (page 55).

Fig. 92 is the La France engine (page 55).

Fig. 93 shows a section of the Amoskeag engine and boiler, and Fig. 94 shows the Gould engine (page 56).

Fig. 95 (page 57) shows the Silsby boiler, with the Field-tubes; Fig. 96 (page 57) shows the Clapp & Jones boiler; Figs. 97 and 98 (page 58) show the Latta boiler; and Fig. 99 (page 58) is the La France boiler. Water-tube joints are liable to be damaged by careless stokers. Figs. 100 and 101 (page 58) show the La France engine and pump. The engine is fitted with a side packing-plate to prevent leakage of steam, and there is a take-up plate adjustable from the outside in the pump.

Figs. 102 and 103 (page 59) show the Silsby engine and pump. The sides of the steam-pistons have shallow holes countersunk in them to act as grooves to pack the sides against leakage. The trouble with side-packing strips is their unequal wear, at different distances from the center of motion.

INDEX.

REPORT

ON

WOOL AND SILK MACHINERY.

BY

KNIGHT NEFTEL, C. E.,
SPECIAL AGENT.

TABLE OF CONTENTS.

LIST OF ILLUSTRATIONS.

REPORTS ON WOOL AND SILK MACHINERY.

MACHINERY USED IN WOOL MANUFACTURE.

Probably the first materials woven into continuous cloth—wool—necessitated for its treatment some mechanical device to transform the short fibers into a fabric. The same process devised in the first ages of civilization has remained to the present day, viz, producing a long continuous thread from the short fiber, and then weaving these threads into a compact network. The wool industry has perhaps grown quite steadily without sudden or great improvements during any short period, the machinery having gradually improved both as to workmanship and efficiency. The greatest impulse given to this industry, which it shares with many others, was the application of steam power, enabling the spinning and weaving to be done automatically. It is only lately, however, that the entire process is performed by power machinery, many of the older mills still running hand-jacks for spinning.

In this country the growth of the manufacture has been gradual and parallel with the improvement of the machines. This steady increase is due to the fact that wool, whatever the condition of finance, business, or other important factors, is a staple absolutely necessary for existence in our present civilized state, and hence but slightly dependent on other considerations. This may appear untrue at first sight, but is of course a mere relative statement in comparison with other industries, such as silk, jewelry, etc., etc. It is of course true that rich tapestries, heavy carpets, and many similar productions may suffer during periods of depression, yet the main business—the manufacture of cloth for clothing and like purposes—always finds an ample market, unless greatly overproduced.

The use of machinery has played a most important part in the progress of the industry. In the first place, it would be impossible to produce the annual amount of goods consumed at present by hand or any other method. Formerly weavers, and those skilled in the process, constituted, like the present iron-workers, a class, upon which the manufacturers were much more dependent than they are at present. In the spinning department alone, even only a few years past, were the jack-spinners to strike, the stoppage of the whole mill would follow.

Secondly, the machines at present in use have enabled the production of a better quality of goods and increased the profits of the manufacturer both by diminishing the cost of production and by causing a greater demand for a better class of goods. In the opinion of many manufacturers it is believed that for the past twenty years the improvement in the machinery, and the consequent advance in the industry, has been at least 25 per cent. At present, with but very few exceptions, the quality of products has equaled, in some cases (for practical use) excelled, foreign manufactures.

Steam power has perhaps, as just stated, had more influence on this industry than in parallel ones. The treatment of the wool and its dyeing, necessitating a large amount of heat, steam, and water, involves inevitably the use of boilers to a great extent. The power thus becomes but a factor in the steam plant, not the sole object, as in cotton manufacture; hence the fact that it is more economical to locate a woolen mill conveniently to points of demand and supply than to place at a water power. Steam is absolutely necessary in the process, and but a comparatively small increase in the steam plant will cover the power. Auxiliary water power, if accessible, may be a source of economy, but in the location of a new mill the other considerations are of greater importance than this question of power.

The greater part of the machinery in our mills is of American manufacture. In some of the older mills foreign machines are still in use, but are invariably replaced when new ones are wanted by domestic appliances. In many mills the reason for retaining old machines is either the conservative spirit of proprietors (this is, however, rare in face of competition), or more often the fact that a profitable business is carried on and the first cost of new machinery a bugbear.

In most cases all American wool machinery is but improved foreign design. For many years no very notable new mechanical contrivance has been introduced which would have a revolutionary effect. The English loom has

been greatly improved, but does not differ essentially in principle from the first power-loom. The Jacquard attachment for figured goods has likewise been increased in efficiency, but is the same machine. The spindle now running in our mills with remarkable speed and steadiness is but an improved form of the first spindle brought to his country.

There have been many new inventions, which have improved the various machines and greatly assisted in the general advance of the mechanical efficiency, yet there has not been any new departure or novel idea of transforming effect, such as there has been in many other industries, since 1776. This is, perhaps, due to the fact that the process has become reduced to its simplest form consistent with the quality of the product, and the machinery direct and appropriate. Usually a new invention, of great and widespread value, is the result for an almost imperative demand by circumstances for such an idea. Wool manufacture has grown, the business is profitable, and manufacturers of machinery are bent simply on improving present forms, without introducing new ones. The total improvement over hand labor can barely be estimated as an absolute value, for the present efficiency cannot be obtained. In the principal operations the increase has been about as follows: In olden times a woman could card 1 pound of wool a day by hand. At present one operative, with the necessary machinery, can card 100 to 125 pounds a day. Hence the improvement is about 125. On a spinning-wheel a woman could produce daily 2 skeins. An average mule to-day spins about 500 pounds; hence the improvement is about 560. On a hand loom it took a day to weave 2 to 3 yards. Power looms produce from 35 to 50 yards a day, or an improvement of 17. Hence, disregarding all other factors but these, and placing a modest estimate, it is possible at present, with power machinery, to produce over 700 times more goods to-day than in the olden time with the same number of hands, and disregarding the quantity, design, etc.

It may be here stated that the difference between hand-jacks and looms is about as follows: Hand-jacks, 48 cents a 100 run; mules, 20 cents a 100 run; or less than half.

In general one set of woolen machinery will require 26 horse-power to run. Worsted machinery needs about 25 horse-power per set. A set of woolen machinery consists of a set of cards (two peakers and one finisher) and the necessary amount of machinery to convert the wool from these into yarn or cloth. This amount varies according to the class of goods manufactured, the opinion of superintendents, etc.

Before describing the various machines used in the process, of which only the principal ones can be detailed, owing to the immense number of various appliances, a short description of the process will enable one to comprehend the relative position and duty of the various machines.

PROCESSES.

The various products of wool manufacture are so numerous and of such different natures, that a complete account of the details would fill many pages. Wool, besides being made up into various cloths, yarns, etc., is mixed with other materials, such as cotton and flax, and a process different in some of its details is involved. Wool, besides, is graded, according to the length of the staple, into wool and worsted, the latter being the longest and requiring certain preliminary operations which are not necessary for the short staple.

The usual process for "coatings", etc., is as follows, with but slight variations: The wool is first thoroughly dusted on machines to remove the grosser impurities and prepare for the subsequent washing. Wool, unlike other textile raw materials, is brought to the mill in an extremely dirty condition. It is received in bundles, which contain each one fleece, and as shorn from the sheep, in its natural grease, containing sand, dirt, and often other matter to increase the weight when sold. Fraud is often perpetrated, the inside of the fleece being filled with "pulled wool", or wool pulled from dead animals. It is usual to wash the sheep before shearing to remove part of the impurities, but in some cases, when the animal is valuable for breeding purposes, this is not done, to prevent sickness.

After the preliminary dusting the wool is passed through a washing machine and scoured. This machine, described further on, removes the last vestiges of grease, and leaves the wool pure and white. It is then either dyed, called wool-dyeing, or is first picked, carded, and spun, and then dyed, called yarn-dyeing. In some cases the wool is not scoured, but is run on the cards in its natural condition; this, however, causes the separation of much dirt at the cards. Before the scouring the wool is carefully sorted into various grades, the number depending on the kinds and qualities of the goods manufactured at the mill. This work has to be done by skilled labor, as there is but one way of separating the various grades; that is, by the sense of feeling. The difference in these qualities may be stated as being the difference in the number of fibers per ounce; that is, a difference in the fineness of each fiber. The length of the staple is also a factor in this sorting. Much weight is lost during the scouring, varying greatly according to the amount of grease, etc., in it. The weight of 100 pounds is often reduced to 30 or 40 pounds—even less. After the dyeing the wool is dried roughly in a centrifugal machine, termed an extractor. It is then taken to the drying-room, exposed in a machine to the action of a current of hot air for several hours, and every vestige of moisture removed. It is next conveyed to the picker, a machine which tears the bunches of fibers apart and spreads them out into the shape of a sheet, being the first mechanical separation of the wool. It

is next carded, or the fibers brought parallel by a system of cards or combing-machines described further on. There are usually three carding machines to one set; that is, the wool passes through three of the machines, graded so as to gradually reduce the sheet of tangled fibers into continuous skeins of soft wool. This is spooled, and is ready for the subsequent twisting or spinning. This is effected on spinning frames, mules, or jacks. The two former are automatic, the latter needs the assistance of an operative. As referred to previously, the jacks are being rapidly displaced by the self-operating mules.

After spinning, the wool is spooled and run into a beam for weaving. This consists of a series of parallel threads, obtained by a mechanism described further on. The warp is then placed on the loom and the cloth produced. The weaving machinery of to-day, described in the succeeding pages, has been notably improved, yet the improvements are solely in the details and not any radical change in the principles involved. Perhaps the most prominent innovation of late years is the positive-motion loom, in which the shuttle is carried at a certain definable speed instead of being shot through the loom by a picking lever. The cloth is well beaten up, of even width, and thanks to the faultless operations of the Jacquard and chain systems, the figures and artistic vari-colored effects are produced with uniform regularity and without as great trouble in reducing from the design to the loom as formerly. From the loom the material is taken to the fulling-machine, which saturates it with sizing and beats the cloth into a compact mass. The cloth shrinks considerably during this operation and has subsequently to be tentered or stretched. Considerable improvement has been made in this portion of the process by the adoption of rotary fulling-mills, which reduce the latter by a half, incidental to the old fulling stocks. The cloth is next dried and then gigged on special appliances for this purpose. These consist of machines, which raise the nap on the cloth generally by the use of rows of teazles, which comb the projecting fibers. These are then sheared to an even depth on a shearing-machine, resembling in principle a lawn-mower. The cloth is then usually measured and wound on automatically winding appliances, sometimes finally stretched and pressed or rolled between rollers to give softness, and packed for market.

WASHING, CARDING, AND SPINNING MACHINERY.

After the preliminary sorting of the wool and dusting it is washed. Several machines have been devised, and, as it would be impossible to describe them all, one has been taken as type, the principle being about the same in all. This is Sargent's wool-washing machine. (See Fig. 1.) The machine consists essentially of a series of bowls, through which the wool is impelled by rakes, some movable and others stationary, and which contain a solution of scouring liquor. The wool is placed on the feeder (on the left of the figure) and is dropped into the first bowl, back of the first stationary rake, which, similarly to the others, swings a small amount on its suspending pivots. The portion of the wool is drawn through the rake by the first movable rake, which has long, curved teeth, which penetrate between the teeth of the stationary rake, and thus draw out the fiber. The machines are built of different sizes, with different numbers of rakes, this process of drawing through being repeated two, three, or four times. The motion of the movable rakes is peculiar and ingeniously arranged. They are hung on a crank near their center, and the upper end operated by a swivel-stand. The motion of the teeth is therefore that of an ellipse, being nearly a straight line at the lower portion of the motion. The effect of these successive drawings is to thoroughly saturate the wool with the liquor and to loosen all dirt, grease, etc. The last rake draws it from the bowl and places it on the "convex table", an arrangement shown on the right of the figure, and which consists of a cylinder of large radius with projecting teeth; this catches the wool. A swing-carrier, with jointed teeth, arranged so that on the backward motion they slide over the surface of the wool, is connected with the rake. When the motion is reversed the teeth remove the wool from the convex table and places the wool so as to be engaged in a pair of rolls called the squeeze-rolls. This arrangement is claimed by the makers to be of special efficiency, as the wool is carried to the rolls in an even mass of almost uniform thickness, thus insuring a uniform pressure at every point of the rolls. These rolls are arranged with spring-lever and weight, and a pressure of nine tons can be procured on the wool. The wool is almost completely dried by the rolls, the liquor passing to the end of the bowl. Some of the rolls are covered with rubber, and have been found to leave the wool almost entirely free of water. The wool is taken off by a beater or fan or an apron.

When several bowls are used the quality of the liquor is of course best in the last bowl and worst in the first. It is drawn off from the latter and is let in from the former by a steam jet. Steam is likewise admitted during the process to keep the liquid at a proper temperature, and the condensed water of the mill is used to save time in heating the liquid when the machine is first filled and to save steam in the subsequent operations. For maintaining the proper temperature steam is injected in each bowl in small jets by a perforated pipe. The machine is claimed to wash wool as well in the hot months as in the cool; a feature which is not usually possible in the old method of tub and rinse-box. Fig. 2 gives a perspective view of the machine and a better idea of the rake mechanism than the elevation Fig. 1. Figs. 3 and 4 show two varieties of dusters for the preliminary removal of gross impurities from the wool. The machine consists essentially of a cylinder with teeth, which separate the wool loosely. Meanwhile it is subjected to a blast. Fig. 3 is the larger and more complete machine.

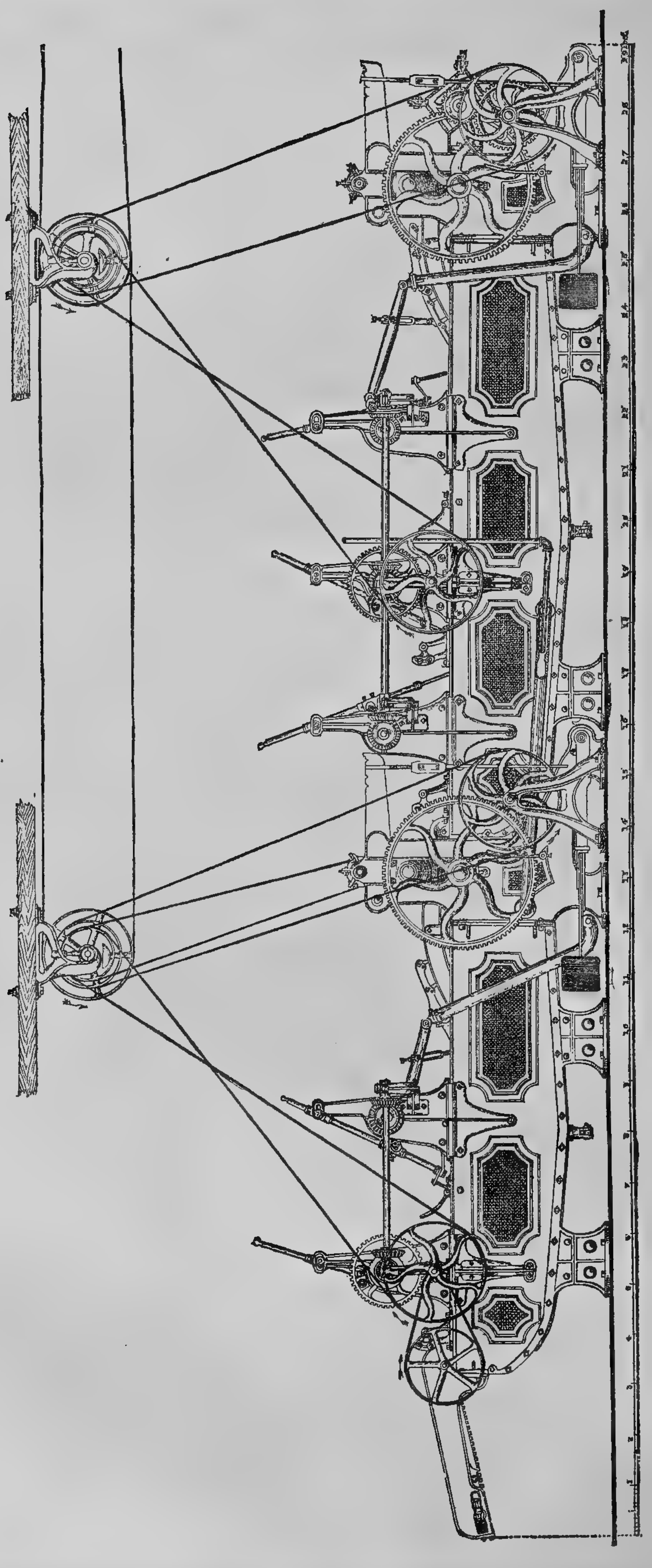


FIG. 1.

From the washer the wool is taken to the drying-machine, of which several forms exist, the principal being that the wool is placed on wire netting, air is drawn by a suction-fan through a coil of steam-pipes and is blown through the wool. The machine shown in Fig. 5 can, by simply reversing the fan, be converted from a hot into a cold-air machine.

The burr-picker is the next machine which treats the wool preparatory to the spinning. The machine shown in section in Fig. 6 is of recent invention, and may be described as an example of this class of machinery. The

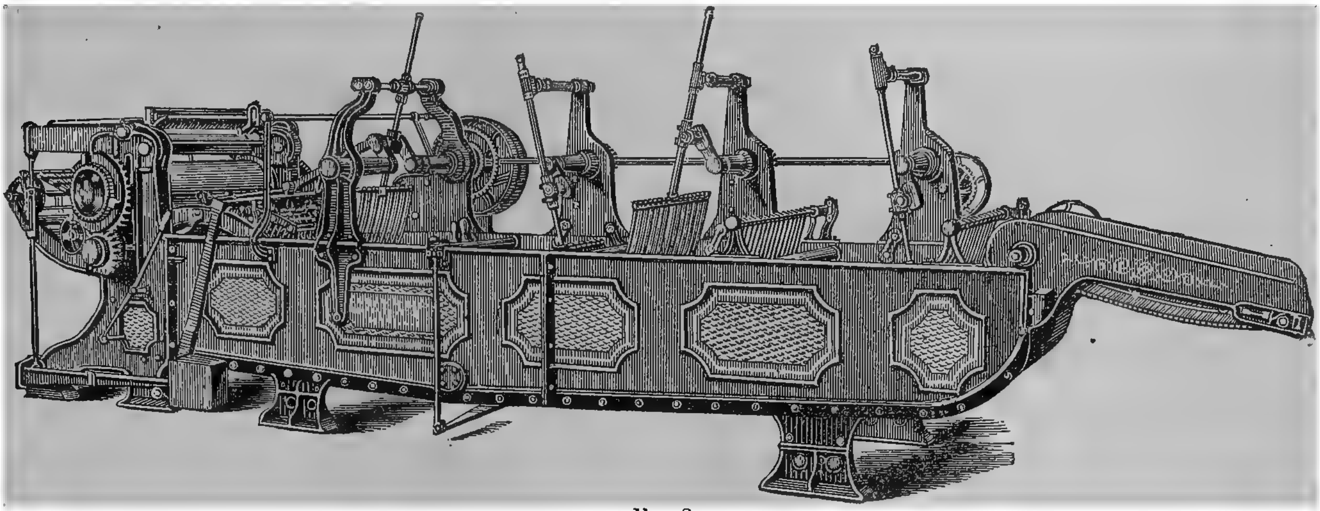


Fig. 2.

advantages claimed are the separation of the wool into four subdivisions, each portion being kept separate. The light impurities are drawn through the fan, and thus separated from the heavier scurf, dust, etc. Burrs, sticks, and straws are separated into a third receptacle and the clean wool into a fourth. The machine is supposed to obviate the opening of the burrs, which are vegetable fibers in knots, and, ultimately, if opened, get in with the wool fiber

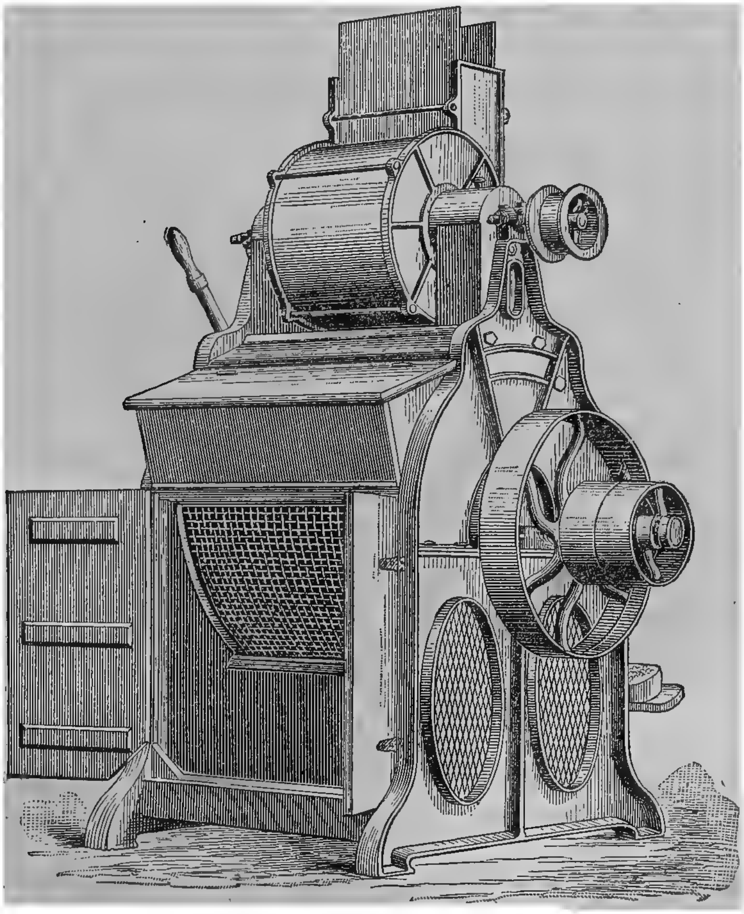


Fig. 3.

to prevent the loss of wool and the mixing of it with already separated burrs. Another claim is, that owing to the immediate separation of the burrs, the gratings under the picking-cylinder can be made fine so as to obviate the dropping of wool through them and consequent loss. The machine is built by Charles G. Sargent & Son.

A is a screen through which the light dust, etc., is drawn through to the fan P, and thrown out at Q. It is removable and can be cleaned, at the same time affording access to the picking-cylinder F. O is the feed-table, which carries the wool to the feed-rolls L M and to the picking-cylinder F. This separates the fibers, which are at the same time subject to the draught of the fan P, which removes the light impurities. H is the burr-cylinder, with its guard I. If too much air is admited under H the light burrs are carried back, but by opening F this may

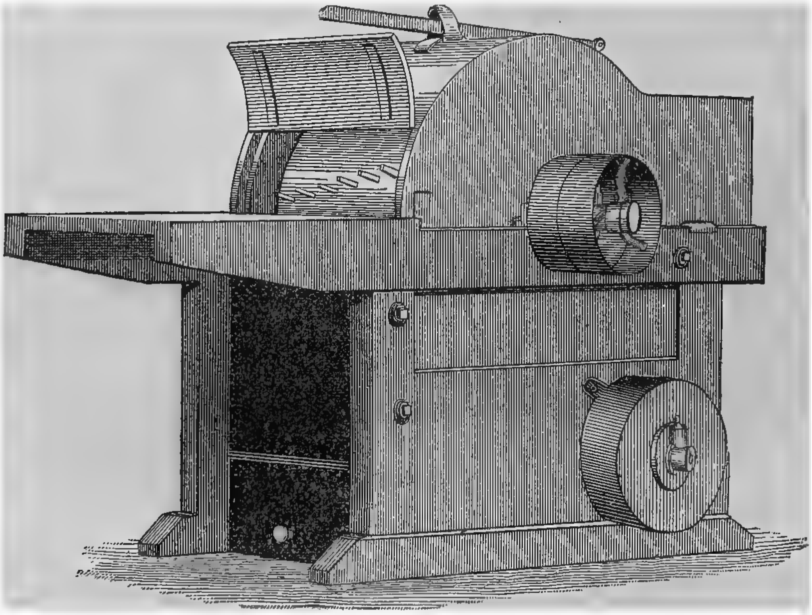


Fig. 4.

be regulated. The rolls L and M exercise a combing action, and liberate the heavy dirt, which drops through the rack G. The wool is thrown back from H by the air currents. J is the brush, which keeps H constantly clear and deposits the cleared wool out at R. There is a difference of velocities in the feed-rolls L and M, which keeps them clear. The picker-cylinder is about 36 inches in diameter and about the same width. It revolves at 500 to 700 times per minute.

During the entire process of treating wool after the burr-picker, it is kept thoroughly oiled with some light oil to prevent felting. The old method, still used in many mills, was to lay the cloth on a brick floor and then

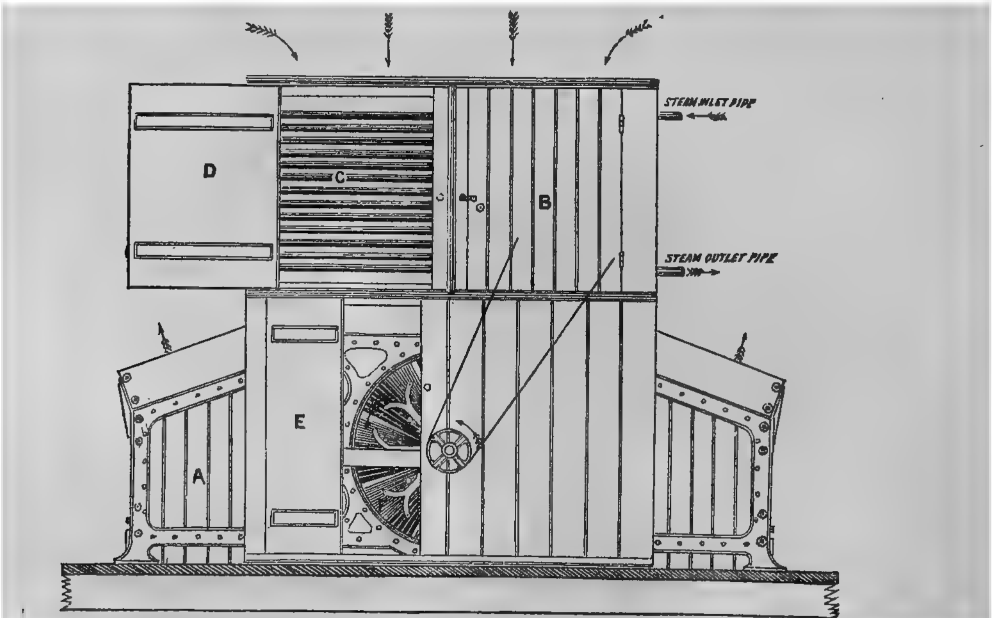


Fig. 5.

thoroughly saturate it with oil. A machine for doing this automatically has lately been devised, and is shown in Fig. 7; it is used before the carding, the next machine in the process, and treats the wool before it enters this machine. It is described as an example of its class. Fig. 7 is an elevation of the machine and Fig. 8 a section view thereof. A is one of the stands upon which the machine rests. B is the oil-tank, which holds about 4 gallons and is about 8 inches abov(the wool. C is the lever-arm on the dipper, which takes up the oil. D is a connecting-

link, one end of which is connected to C, the other to the crank-pin on the eccentric E, giving the vibratory motion to the bucket. E is eccentric and strap connection. It is connected to the brush-shaft I, and gives this a forward

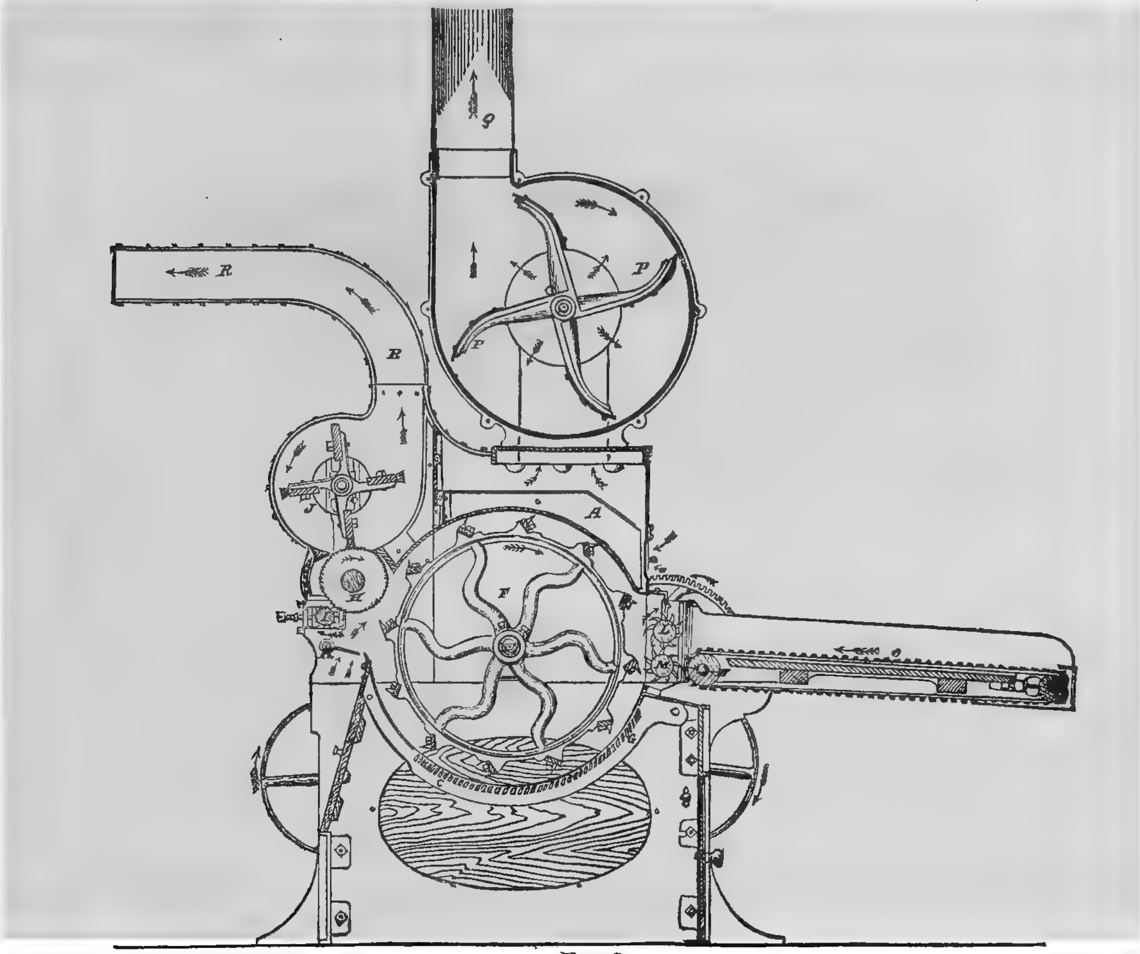


Fig. 6.

and backward motion. K is the dipper or bucket, which brings the oil from the tank to the point of contact of the brush. L is the atomizing brush. The advantages of this machine, claimed by the inventor, are that the oil is

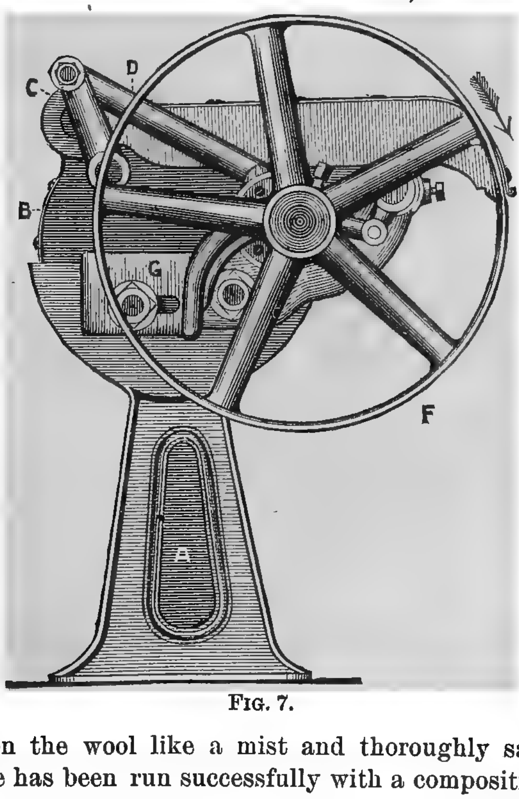


Fig. 7.

completely atomized, and falls upon the wool like a mist and thoroughly saturates the wool. The chance for evaporation is small. The machine has been run successfully with a composition of 1 quart of oil and 4 quarts of

water to 100 pounds of wool. The amount of oil can be varied from 1 to 10 quarts per 100 pounds, and is completely under control of the manager.

The backing of many cloths is increased in weight by the addition of shoddy—a material consisting of rags, new and old, torn up in a picker, and reduced to their original fiber. This is then fulled into the cloth and helps the final texture. A machine for wool-mixing is shown in Fig. 9. It consists essentially of a strong frame, with projecting teeth, revolving rapidly, and feeding table and rolls.

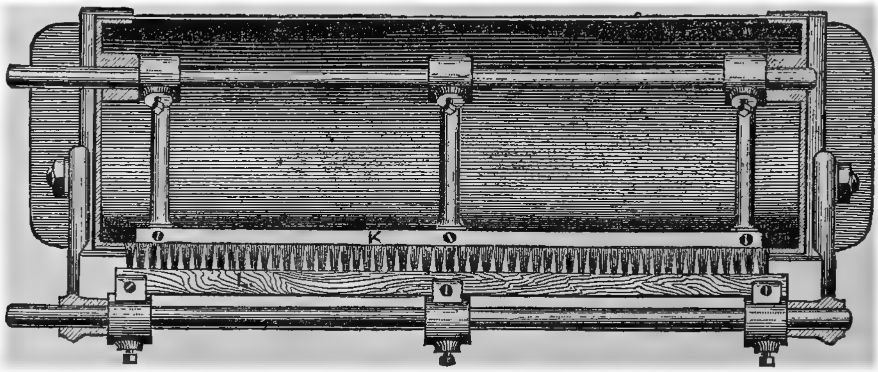


FIG. 8.

Being thoroughly oiled, the wool is next carded. Three carding-machines are usually used to a set, that is, successively. In the carding-machine the wool is combed, the fibers becoming parallel and completely pure, and are by the last operation brought into a tender filament, their first continuous shape. The main organ of a card is the "cylinder", usually about 4 feet in diameter, and covered with card-clothing, which consists of leather strips, in which wire teeth are inserted. Around this cylinder there are several other smaller cylinders, called workers, similarly clothed, which continually remove the wool from the cylinder, separating the fibers and combing them.

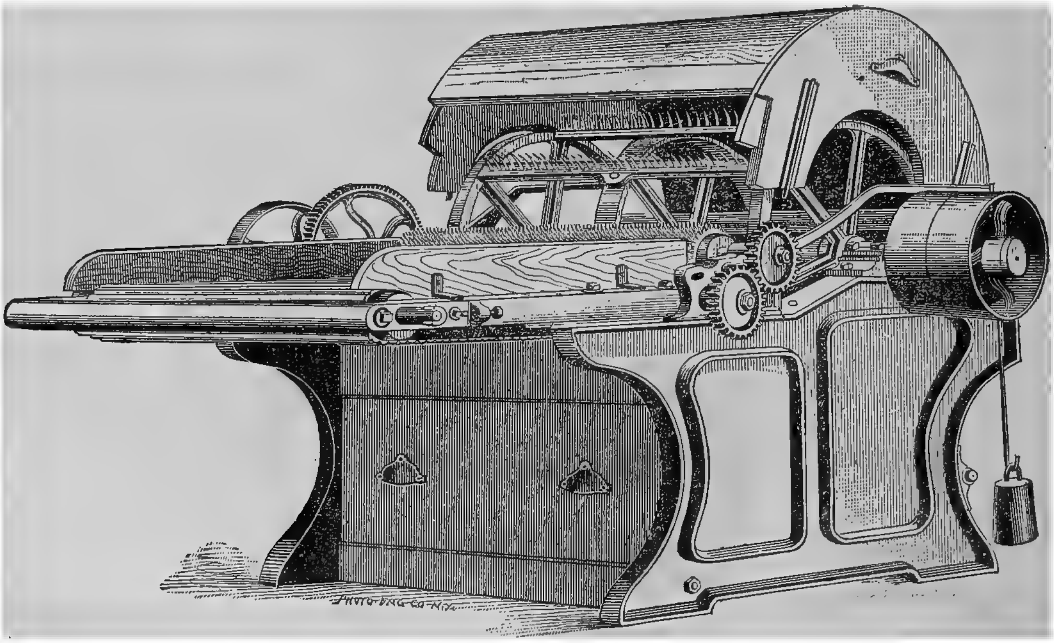


FIG. 9.

From these, as they become saturated with wool, the latter is removed by another roll with longer teeth. This is called the "fancy", and revolves at a considerably higher speed. The carded wool is then removed by a "doffer" and undergoes the same process twice more, each time by finer card-clothing, on what may be considered the remaining portions of the whole machine, and finally removed by a pair of small rollers called condensers. These condensers, one above the other, have strips of card-clothing affixed, which alternate; thus the wool is taken off in long strips. These then pass through more condensing-rollers, which, besides rotating, are given a transverse rectilinear motion, the combination of these two producing a soft and untwisted thread of woolen yarn. Great experience is requisite to operate this class of machinery with efficiency, as much depends on the skill and attention of the operative.

Fig. 10 shows an elevation of the Davis & Furber breaker card, which is taken as a type. On the left is the feed-table, with the cylinder and workers in the center, and the doffer-roll on the right, with its vibrating cone. The sliver is delivered sidewise, as regards the machine, from the roll in front of the doffer. The main cylinder is 48 by 48 inches. The power and other details have been alluded to previously. Fig. 11 gives a view of the finisher

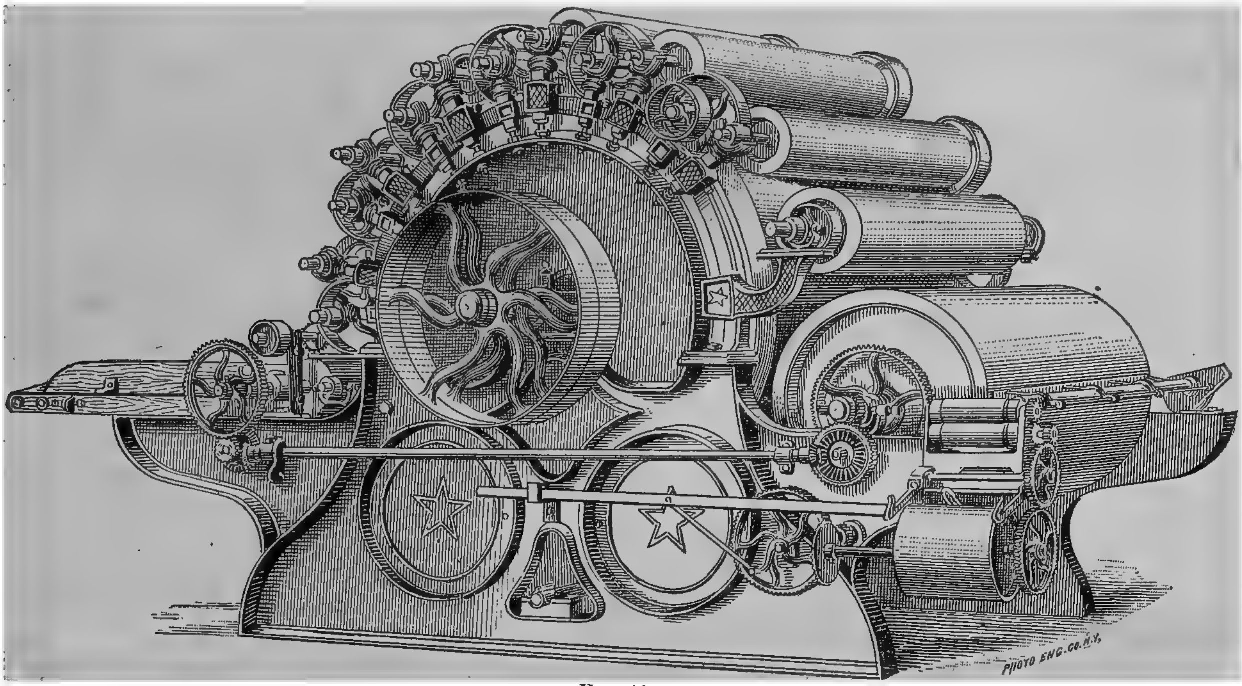


Fig. 10.

card. For feeding from one card to another the Apperly feed is used, a traverse motion being given to the wool, which enables the card to operate on an even mass.

The next principal step in the process is the spinning. In this department the machinery used at present is almost identical with that used for spinning cotton. The various methods for twisting a sliver of mutually adhering

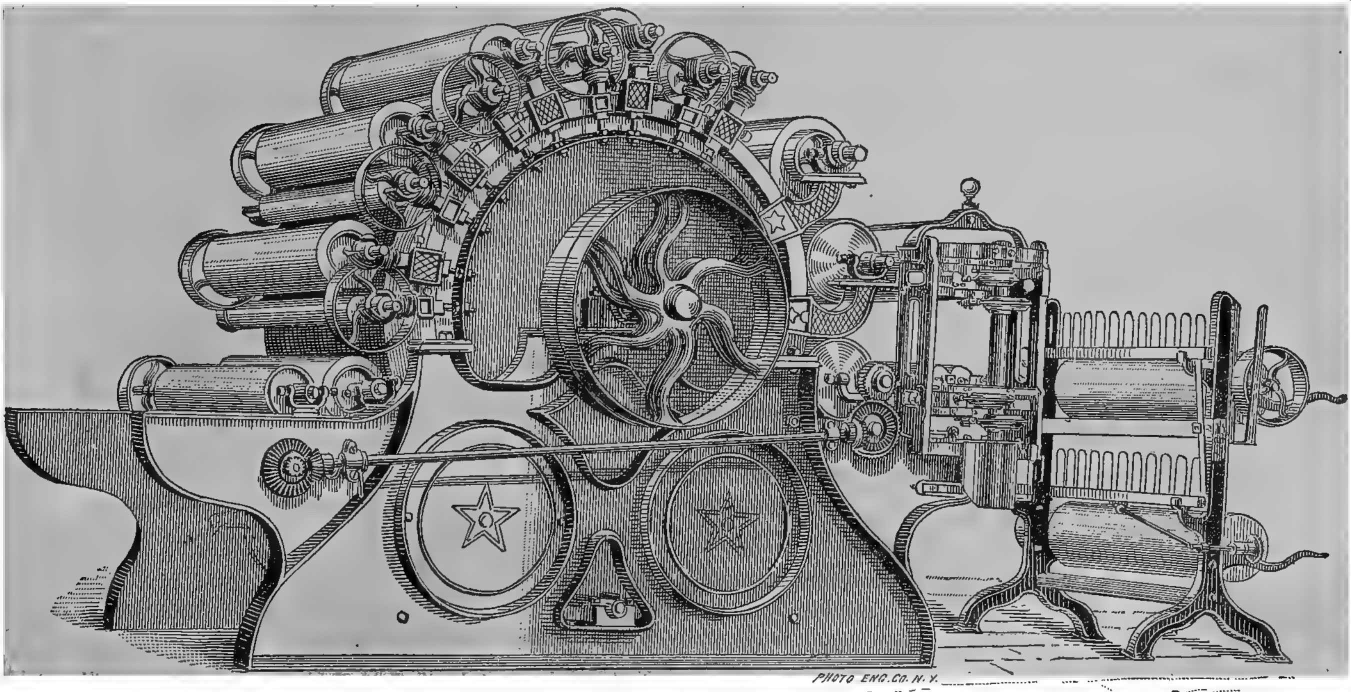


Fig. 11.

untwisted fibers is described in the report on cotton machinery. It may be stated, however, that mules are used to a greater extent perhaps in this industry. Many of the larger mills are running filling on flier and ring frames, though the relative advantages of mule and ring spinning are still debated by interested persons. Figs. 12 and

13 show the Davis & Furber spinning-mules, a type of present practice. The motion is transmitted by ropes, being considered better, as being more elastic. It is adjustable to deliver the amount of roving required. Fig. 13 is a

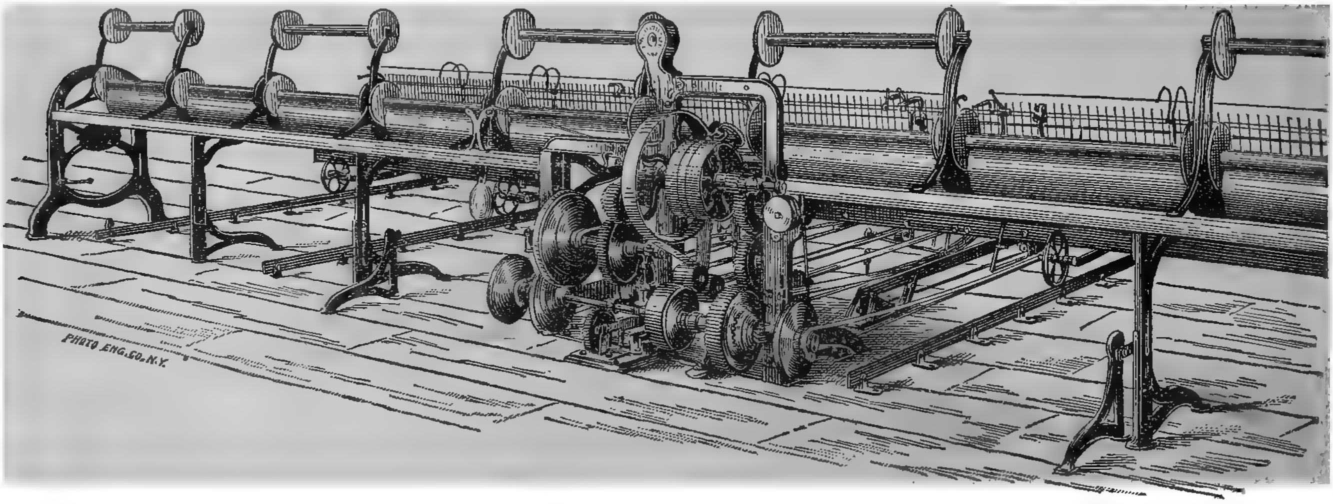


Fig. 12.

front view and Fig. 12 a rear view of the machine. The number of spindles varies according to the necessities of the manufacturer. From the mules, which can be used for second twisting, the yarn is wound in hanks, and if not

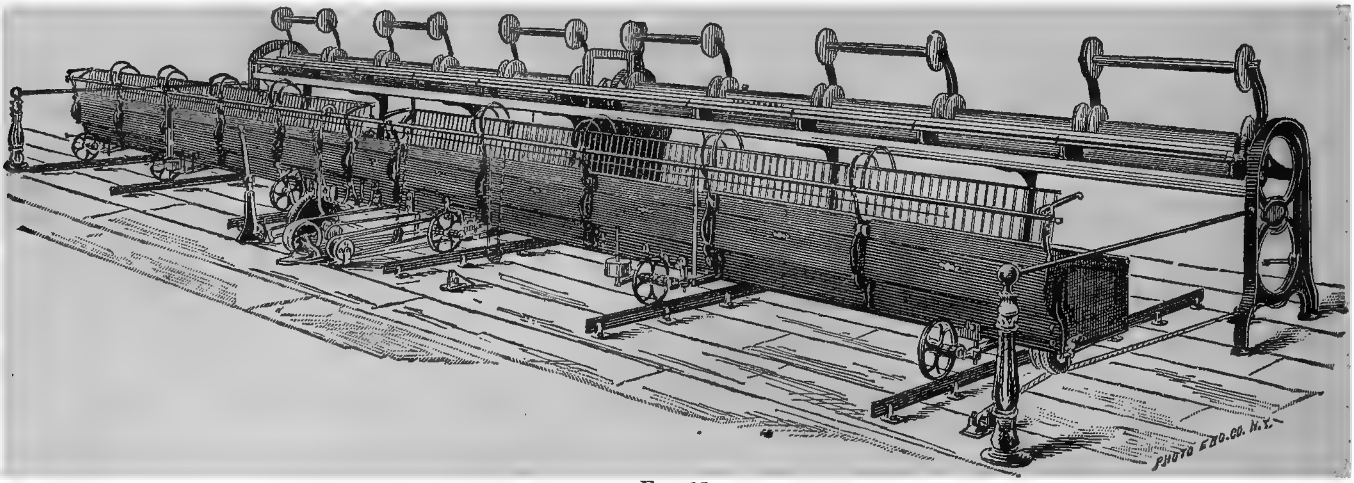


Fig. 13.

dyed in the wool, is dyed in the yarn at this stage, and is then ready for the loom. Filling is wound directly into a cop for the shuttle, and is placed therein ready for weaving. Warp has first to be beamed, and this is done on

Fig. C. Fig. B. Fig. A.

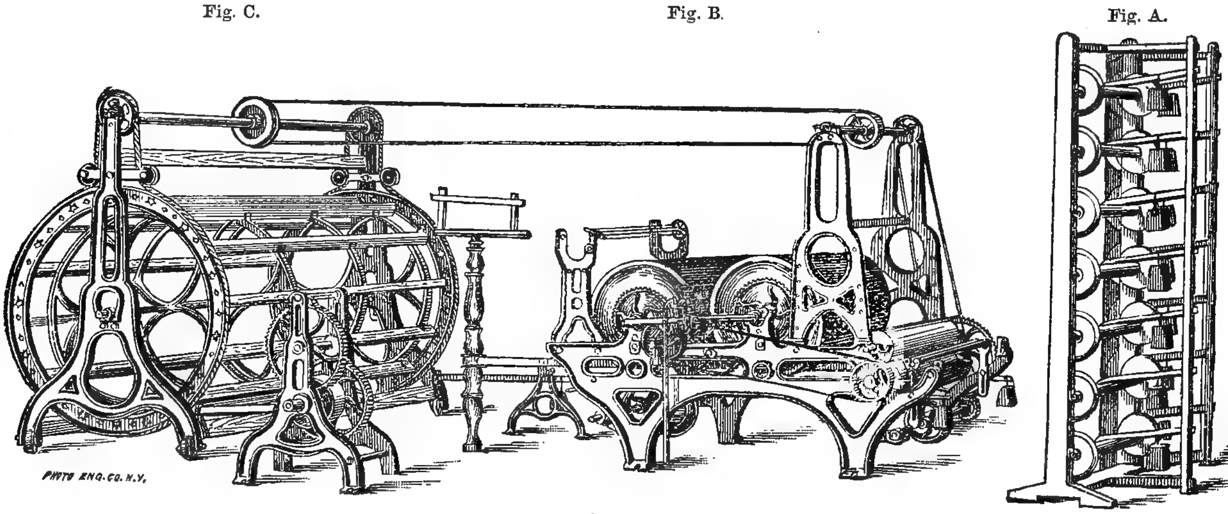


Fig. 14.

the contrivance shown in Fig. 14, which is built by Davis & Furber, serving as an example. The yarn is wound on large bobbins, and is then placed on Fig. A, thence it passes to the dresser, Fig. B, consisting of two copper

cylinders having steam-coils inside. From this it is rolled on Fig. C in a beam, that is, a series of parallel threads, as required by the loom for the warp. Fig. C is movable in the direction of its axis, so as to enable the repetition of parti-colored warps from one set of bobbins to the whole width of the loom-beam, whence the warp is now transferred in one continuous sheet.

LOOMS.

When the yarn has been prepared by the foregoing machines it is ready to be placed on the loom and converted into a continuous sheet. The invention of the hand-loom dates back into the dawn of civilization, but for many centuries nothing but plain goods could be woven. It is only at a comparatively recent date that figured goods and goods of one color and with designs woven in their texture have been produced. The latter varieties, though used at times in wool cloths, are more used on cotton and silk goods, and are simply alluded to here. The improved form of hand-loom as devised by the Kays, father and son, in 1760 is still used in silk, carpet, and other industries. The power-loom, now exclusively used in our mills, is but a modification of this form, though the efficiency and rapidity of work have been greatly increased.

Wool-looms are usually classified, according to the motion of the shuttle, into picking-stick looms and positive-motion looms. Some other forms are in use, such as the needle-loom, which has been tried on carpets, and the rack-and-pinion loom, which, however, is confined to narrow goods, generally silk ribbons. The general functions of a loom are to form a firm stand, on which a series of parallel threads are stretched, called the warp, and which form the foundation of the cloth; to separate these threads so as to pass another thread transversely through the series, either over and below each alternate thread or series of threads; to move the threads of the warp so as to inclose the transverse thread or filling (weft); and, finally, to beat up each successive thread of the filling against the preceding one, so as to make a close continuous fabric. These requirements also involve an arrangement for rolling the cloth on a cylinder and unrolling the warp from another, keeping the threads at a certain tension all

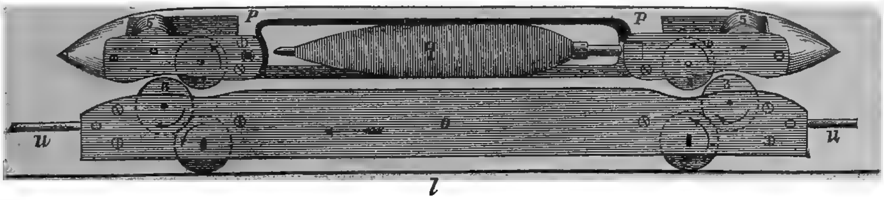


FIG. 15.

the time. This is called the let-off and take-up motions, and they are effected in several ways. Another indispensable contrivance attached to the loom is the temple, which keeps the manufactured cloth stretched to the full width of the warp, as it has a tendency to shrink and thus draw the warp-threads, not yet interlaced by filling, out of parallelism.

The ordinary picking-stick loom for plain goods, represented in the figure, consists of two cylinders or beams, between which the warp is stretched, the number of threads for the texture of the cloth in the width having been determined by experience. Each thread is threaded through a mail, eye, or loop, which is hung by a cord to a lath frame, the whole contrivance being called the harness, of which there are at least two. If the threads are simply to be interlaced with the filling, there are but two harnesses, each alternate thread being on the same harness. If two, three, or more threads are to be raised over or covered under the filling when shot through, and thus a different fabric produced, several harnesses are used, amounting in some cases to 40 in number. When the two harnesses are at the extremes of their motion, the filling is passed through what is termed the shed, being the angle between the divergent threads of the warp. The harnesses are then reversed and the filling beaten against the preceding thread by the reed, which consists of a row of flat wires or small metal slats set in a frame, and through which the warp is threaded. The shuttle, containing the cop of filling, slides through the shed from side to side of the loom in a way. Two boxes are set at each end of this way and receive the shuttle as it is thrown from end to end. The motion is given the shuttle by lever, a sharp rap sending it flying through the warp. Each trip of the shuttle, forming on thread of the filling, is termed a pick. It is evident from the above that though figured and vari-colored goods can be produced by employing warp of different colors and a number of harnesses, yet the number of variations is limited; hence the use of the drop-box, a contrivance which enables the use of several shuttles, each of a different color or kind. The drop-box, invented by the younger Kay, and applied to the hand-loom, simply consisted of a box, having two or more shelves, in which the shuttle was held. The whole contrivance had a vertical motion, which brought the various shuttles on to a level with the way and the picker, or hammer, which impelled them. This contrivance has been adopted on power-looms, the motion of the box being caused by a chain and a number of shuttles used. Thus, with arrangement of the warp, of the harness, and of the motion of the shuttles. To cause the motion of the harness and drop-box to occur at the proper times an arrangement consisting of two endless chains, having small bars between their links, on which are fixed projections,

so that the lever corresponding to a certain harness is engaged and the harness moved. A similar arrangement operates the drop-box. The principle of this contrivance is taken from the Jacquard attachment, which is alluded to further on, and which operates each warp-thread separately, instead of the whole harness, the heddles or threads holding the mails or eyes being separate.

An ingenious contrivance has been introduced on some looms, which consists of a circle operating a projecting rod. When the shuttle enters into the box it pushes the circle and prevents the rod from deflecting the belt. Should, however, something prevent its entrance, the rod is not displaced and the loom is stopped.

Positive-motion looms are looms in which the shuttle has a positive motion at every moment of its run. This is done by placing it upon a carriage. See Fig. 15.

The warp passes between the wheels 3 and 4, 3 being rotated by 2, and hence the position of the warp-threads is not deranged, the velocity of 3 and 4 being equal to 2, and hence to the speed of advance of the shuttle. Several appliances for regulating the motion of the shuttle, quick at the middle of its stroke and slower at the ends, and for causing dwell in the lay, obviously necessary in a slow, or long-traveling shuttle, are introduced in this loom.

The advantages of this form of loom are as follows, briefly enumerated: The abolition of the picking-sticks or impelling levers, and their sharp motion; the positive motion of the shuttle; economy of power; the unlimited variety of figures, patterns, etc., that may be woven; the great width of the warp, being 24 feet in one case, and

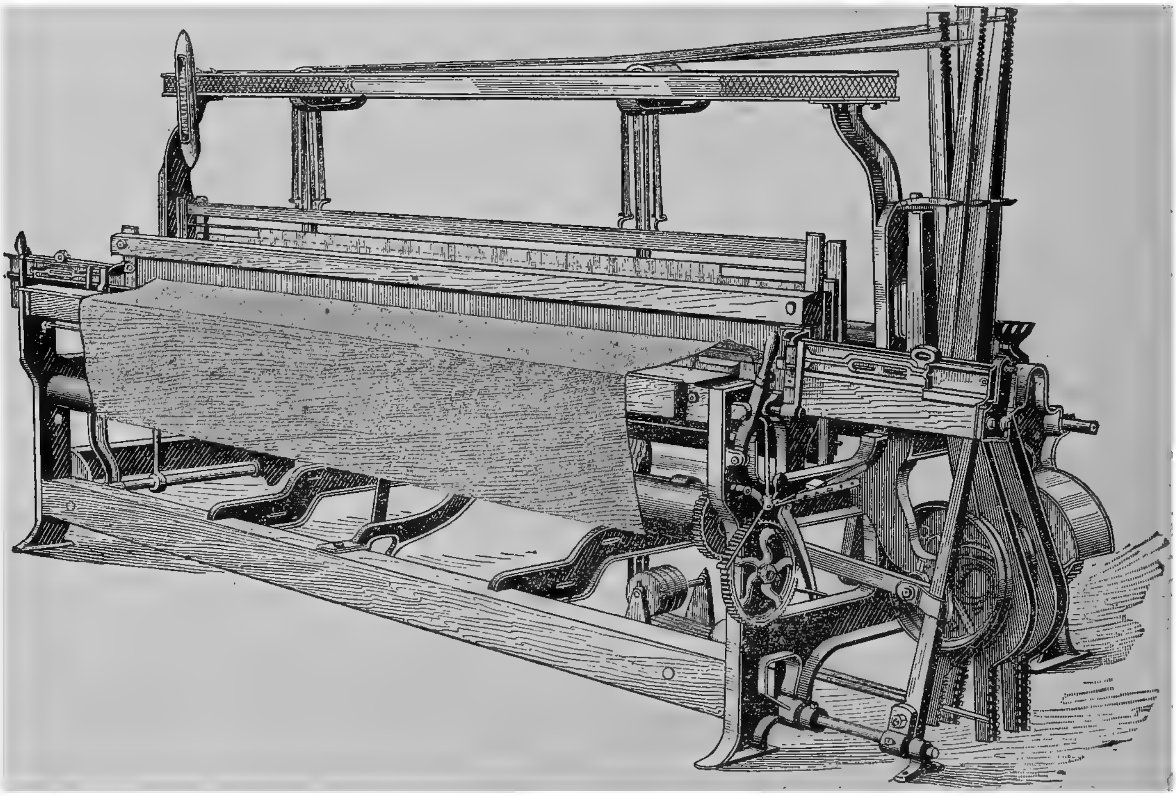


FIG. 16.

the diminution of wear, owing to small motion of the reed, the small opening of the heddles, the abolition of the sudden jerk to the filling in starting, and the almost entire absence of friction between the shuttle and the yarn.

The take-up and let-off motions in the various makes of woolen looms are different, depending on the class of goods manufactured, the extent to which the cloth is beaten up, the number of picks or motions of the shuttle per minute, and the size of the yarn of both filling and warp. The motion of taking up is often done by pawl and ratchet, while the let-off is frictional.

The temple alluded to previously is simply a small roller of wood, with nine teeth, in an iron frame, which hold the cloth steadily stretched. A spring is so attached to the frame as to yield sideways in case of accident. These are the general features, and the following illustrations and descriptions will give an idea of present forms.

A few words should be said, however, of the needle-loom, which has been quite successfully applied to silk-weaving, and experimented with on carpets. The idea is to get rid of the shuttle entirely, and substitute a needle with a split eye, which will catch the filling and draw it through the warp. It is more fully described in the report on silk machinery, in which industry its application is greatest. The Jacquard attachment is likewise detailed therein, as it is of greater use for figured silk goods than in woolen goods, where harness-looms are more generally used. The combination of Jacquard and positive-motion shuttles has been successfully made on corset-looms.

Pile weaving consists of weaving wires into the fabric and then removing them, thus causing a tube of warp to be raised. This is either cut, as in velvet and some kinds of carpets, or is preserved in its rounded shape, as in

Brussels carpets. The mechanism employed is very ingenious, each wire being automatically pulled out from the cloth and placed in front of the series in the shed.

Figs. 16, 17, and 18 represent various cam and fancy looms, and may serve as examples of present practice.

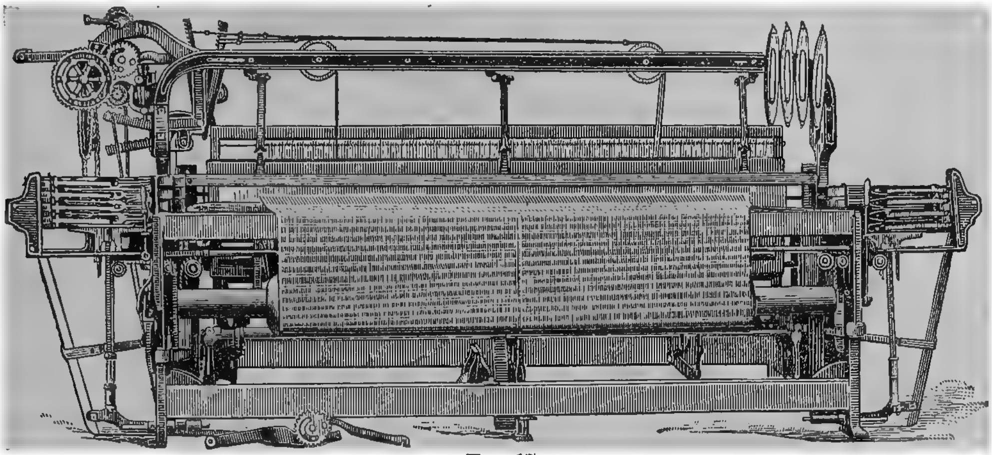


FIG. 17.

Fig. 16 is a cam-loom, built by Davis & Furber. The harness, levers, and cam motion are shown in the figure, and the various parts may be seen and understood from the previous descriptions.

Fig. 17 represents Knowles's fancy loom. The machine is an open shed-loom, its principal advantage being an

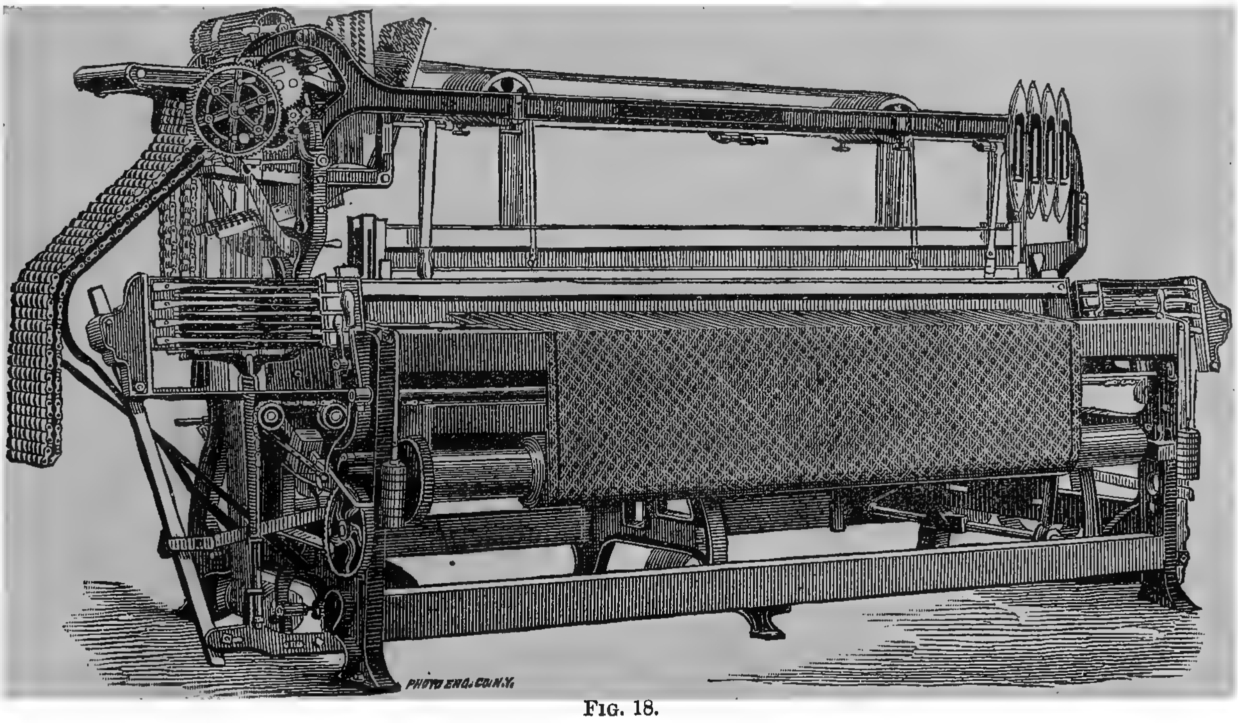


FIG. 18.

arrangement by means of which the chain can be moved by hand, so as to remove filling woven in by mistake, by a retrograde motion of the design-producing machinery.

Fig. 18 is a forty harness-loom, having capacity for seven shuttles. It is one of the largest and most efficient looms of its peculiar style. It is also built by Knowles & Bro. Its construction will be understood from previous descriptions.

FULLING-MACHINES.

After the cloth has been woven it is necessary to remove the oil with which it was saturated before carding, to press together the fibers, introduce a certain amount of shoddy or backing, and sometimes sizing. Formerly this was done by falling stocks, a cumbersome, noisy, and comparatively inefficient machine. These are now being superseded by the rotary mills, in which the cloth is treated by pressure, insuring a better fulling, with less power and attendance.

As previously stated, the reduction in labor, as estimated by manufacturers, is about one-half.

Fig. 19 shows a modern fulling-machine in section. The cloth enters the machine at R', and is conveyed by the machine to the main cylinder, A, then beneath the rolls B^3 B^2 B^1, and finally comes out through the trough C D E. The ends of the cloth are joined; the machine started. The fulling crosswise is effected by the rollers B^3 B^2 B^1, which have a tendency to draw it out, hence to contract the warp together. The fulling lengthwise is produced by the sides of the trough C D E, which can be regulated by varying the weight M. The machine is

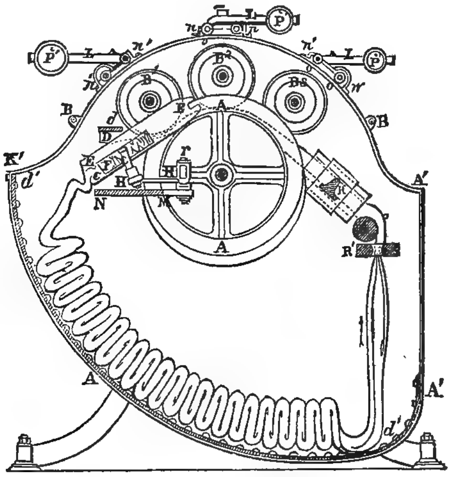


FIG. 19.

entirely under control. A beating motion is sometimes added, by revolving or reciprocating beaters on a fulling-table.

CLOTH-FINISHING MACHINERY.

After the fulling the cloth must be freed both of the water, which mechanically adheres to it, and its hygroscopic moisture. The former is done on centrifugal machines, which removes the greater part. For the latter artificial heat is employed.

From the drier the wool is taken to the tentering-ground and stretched in the rays of the sun. This operation

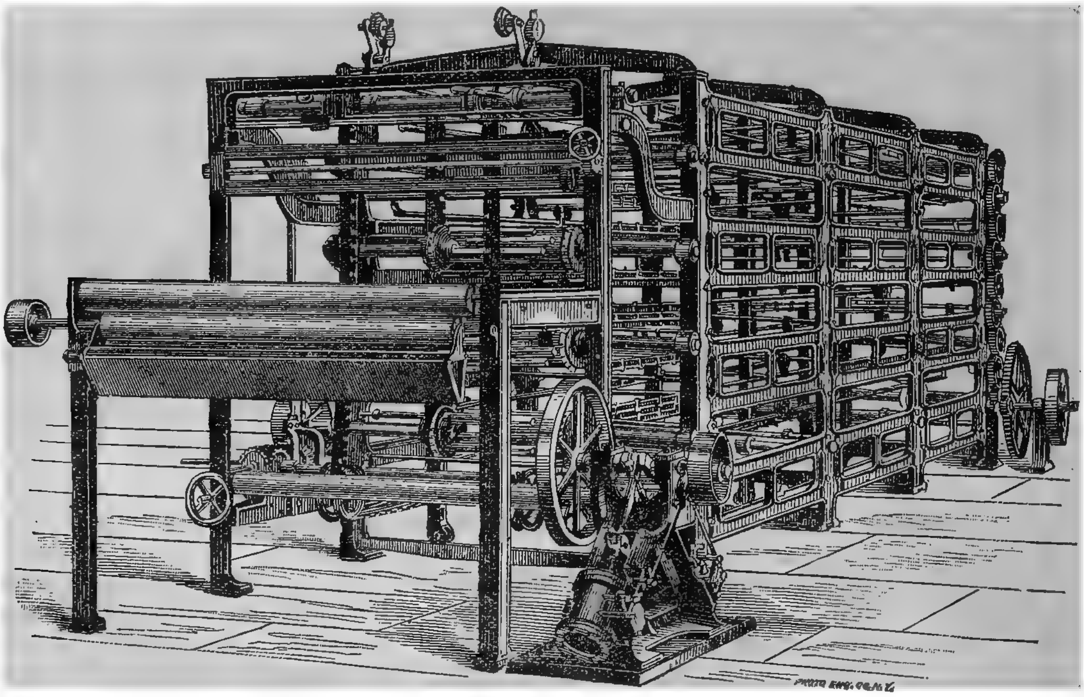


FIG. 20.

is now seldom performed in this manner, except in the smaller mills; those of any size using tentering-machines almost universally. These, combined with drying-cylinders, are shown in the accompanying Fig. 20.

After the latter operations the cloth is gigged, sheared, brushed, measured, and folded, each operation requiring a special machine. Gigs are contrivances by means of which the nap is produced. They usually consist of rollers for winding the cloth, firmly stretched in the intervening space, and operated upon by rows of teasels.

Fig. 21 is Woolson's gig. It is usual to steam the cloth during the operation, hence the kettle arrangement under the main cylinder. This is a species of spider frame, having fourteen flats, to which the teasels are affixed.

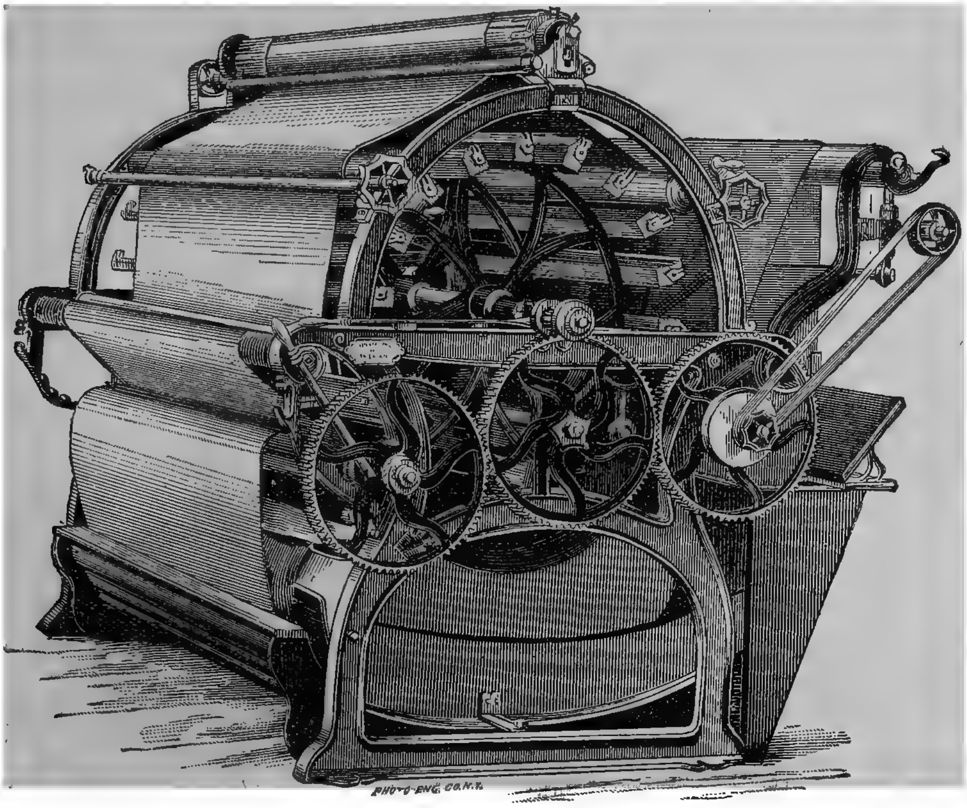


FIG. 21.

Fig. 22 is a wet gig, built by Davis & Furber. In these machines the cylinders are 40 inches wide, making 125 to 150 revolutions per minute. Some of these machines have brushes attached, as in the large gig, by the same firm (Fig. 23). The teasels are on rolls and the brushes on flats. The width depends on the goods.

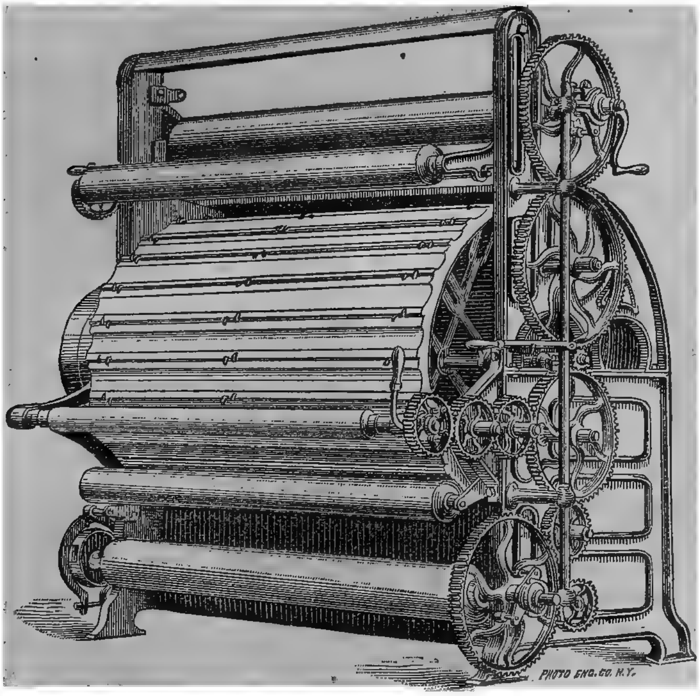


FIG. 22.

Shears for cutting the nap to an even depth are the next machine in the process. Woolson's shear is shown in Fig. 24.

The principle of all machines of this class consists of passing the cloth, tightly stretched between two rollers, over a knife-edge, very close to which revolve spiral blades, like in a lawn-mower. For fine fabrics the cloth is

simply depressed under two rollers and the nap cut even by a knife between. This is due to the fact that thin cloths have little elasticity and cannot resist the action of the other machine. The machine has a guiding tray or pan underneath and 26 cutters. Sixteen to 20 yards may be sheared per minute, it is claimed.

After leaving the cutters the cloth is brushed on separate machines to clean the cloth and improve its appearance. Such a machine, built by Parks & Woolson, is shown in Fig. 25. It is essentially the same in principle as the preceding, excepting that a rotary brush is substituted for knives or teazle flats. There are two cylinder-brushes in this machine clothed with bristles. Pressure may be applied lightly to one cylinder and heavily to the other, or the cloth may be pressed on both equally. Sometimes a steaming attachment is affixed to these machines to steam the cloth while thus being operated upon.

Fig. 26 shows a measuring machine, the principle usually being the stretching of the cloth and running it over a roller, which shows, by means of gears, the number of revolutions, and hence the length passed over. All the

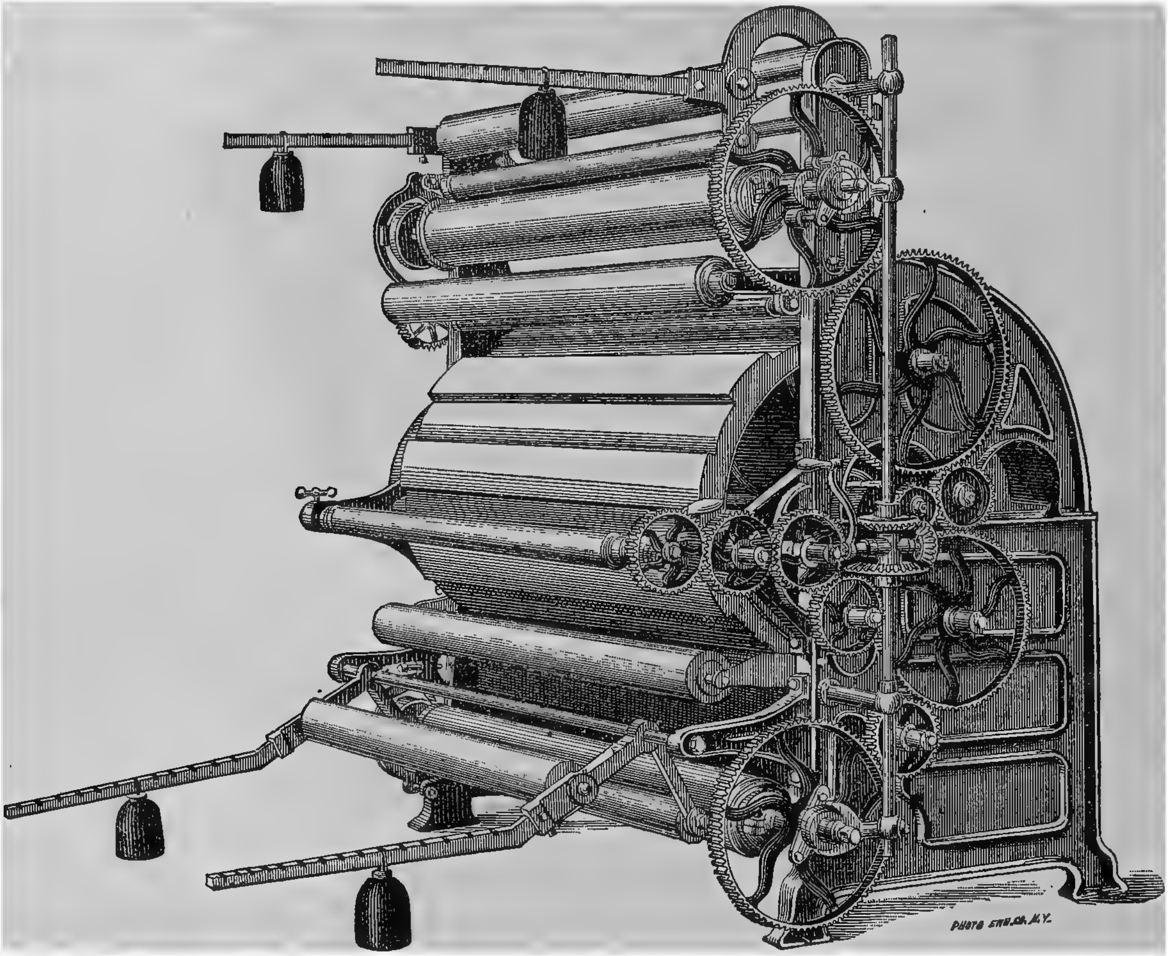


Fig. 23.

latter machines are by the Parks & Woolson Company, and are given as examples of a class. After the final winding or folding the cloth is ready to be packed. In mills where the cloth is packed in pieces these are placed in a folding-machine and then pressed. A final inspection is made, the pieces ticketed, and the product is ready for the market.

WORSTED AND CARPET MACHINERY.

Worsted is long staple-wool, the fibers being considerably longer. The process of manufacture is almost identical with that of ordinary wool, the same machines being employed, with one or two additions. The material is, however, treated differently, and the amount and method of carding, though on the same machines, depends on the product. Skill and experience are required in a high degree. A general outline of the process is as follows, as carried on in one of the largest mills in New England: The wool is first sorted by hand in classes, as in the general process. It is then washed twice in good soap and entirely freed from impurities. The longer fibers are then prepared on preparrers and Lister combs. Medium and short wool are carded, and then combed on Noble combs. The next operation is drawing. This is done on drawing-frames, in gill-boxes, and on roving-frames. The spinning is on cap-frames for short and medium wool, and for long wool on flyer-frames. The weaving, as in the general process, is done on either plain looms, on shedding, or on Jacquard looms, according to the design required. Worsted is often mixed with wool and other materials and woven in with them.

The object of the preparers is to loosen and straighten the fiber, and the combs remove the short staple in the shape of noils and bring the long wool into a sliver. Although no great improvements have been made during the last ten years in the carding, still, by paying attention to the details, the efficiency has been increased about

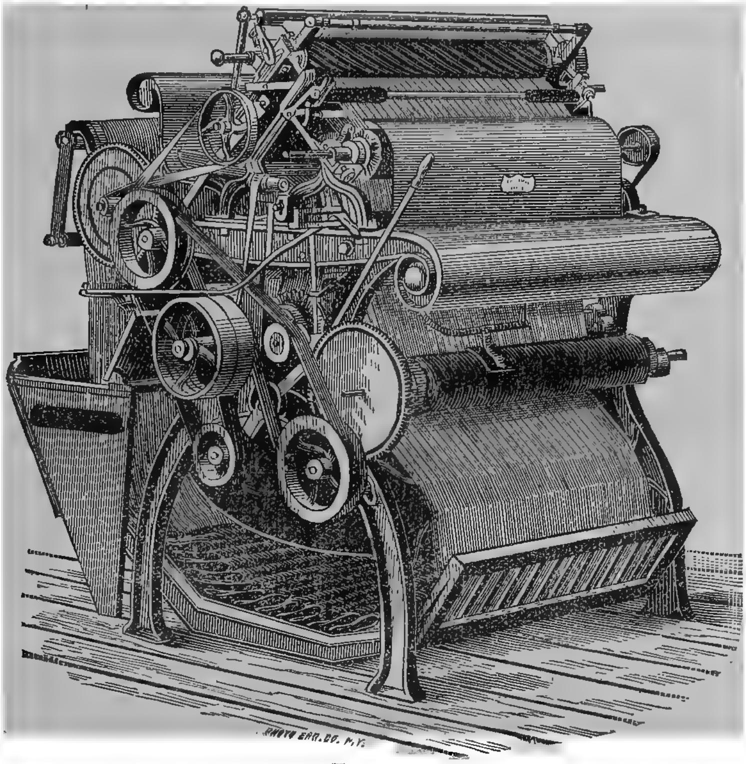


FIG. 24.

25 per cent., and the quantity of the product about an equal amount. In 1870 the product of one comb was about 400 to 450 pounds a day. At the present time (1880) this product is about 700 to 750 pounds with the same labor,

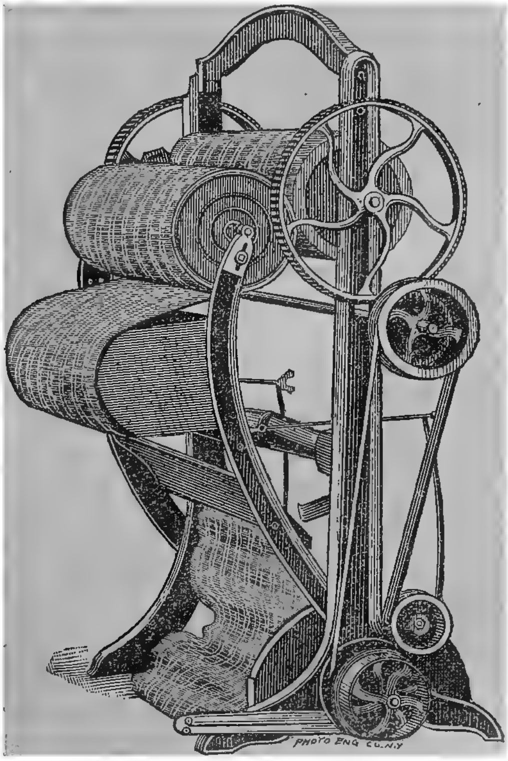


FIG. 25.

yielding at the same time a better quality of product. Thus the cost of combing has been reduced about 25 per cent. The object of the gill-boxes, drawing- and roving-frames, is to draw a large number of slivers into a small uniform roving, ready for spinning. The improvements have been gradual, being noticed only in the increased

efficiency, which is also about 25 per cent. The worsted thus prepared is generally used for filling on the looms previously alluded to. The Jacquard attachment was introduced about ten years ago, and at present a double-action attachment is being added, which will increase the speed about 20 per cent.

The machines, excepting the cards and looms, are nearly all English, this class of manufacture being comparatively new; and our machine-builders are only commencing to pay attention to the necessary machinery.

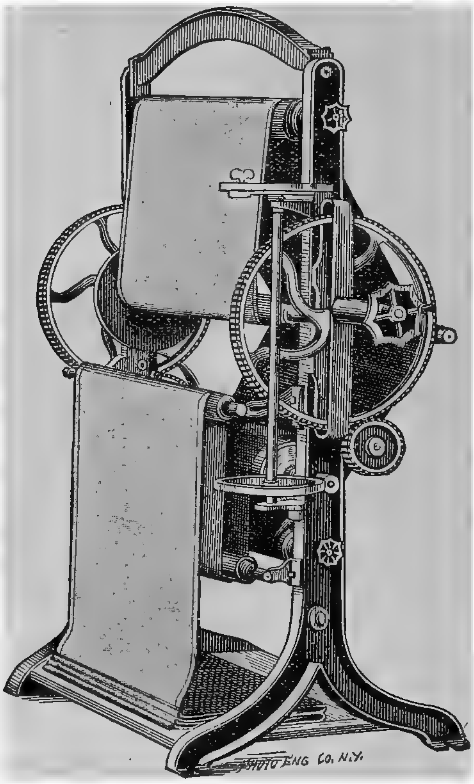


FIG. 26.

Fifteen years ago, at the mills alluded to, only three kinds of goods were made; at present over one hundred and forty styles and patterns are produced; and although the finer qualities of goods are not yet made in this country, still in the qualities that are made our manufactures compare favorably with importations. The manufacture of worsted goods requires a higher class of skilled labor, which is gradually growing up in this country and is replacing foreign labor to a considerable extent.

CARPETS.

The production of woolen carpets is a comparatively simple process, many of the mills purchasing the necessary yarn already spun. The warp and weft are often different materials, and a variety of fibers are used, such as cotton, jute, flax, wool, worsted, etc. A general idea of the features of this machinery may be derived from the following figures, furnished by a prominent machine-shop: Cards, 4 horse-power to a set; capacity, about 400 pounds a day, against 250 ten years ago. Looms: For ingrain, take one-half horse-power, each producing about 30 yards a day; mostly introduced during the last ten years; formerly one hand could produce 14 yards a day. For Brussels, three-quarters of a horse-power produces 40 yards a day, or one-third more, at one-half the expense of ten years ago. These looms are operated by girls, while the foreign looms are operated by men. For Wilton, three-quarters of a horse-power produces 40 yards a day. These have improved about as much as the Brussels loom. For tapestry, one-quarter of a horse-power produces 60 yards a day. The simplicity and speed of these looms has been increased considerably. Shears requiring one-quarter of a horse-power treat 1,000 yards a day.

Brussel looms have an auxiliary arrangement, as stated in the previous pages, which pushes pins in the shed, thus raising the warp into a loop. Several of these pins form a series, and the one nearest the operative being pulled out automatically is placed at the other end of the series in the shed. These pins pass through the entire width of the warp. For wiltons the pins have small knife-edges on the end, the warp-loop being thus cut open when the pin is withdrawn. These brussel looms have often a creel attached, in which are placed the bobbins holding the warp-yarn. This obviates the necessity of warping previously, but takes up much space. Carpet mats are made by hand. First a sheet is woven in streaks, according to a design, and is then cut up in strips. The warp is quite open, the threads being far apart, and serves merely to hold the filling together. The roping thus produced is then used as a filling and again woven on a loom, a new beam of warp being used to hold these strips together longitudinally. By the care taken in weaving the strips at first the design appears in the finished rug. This is a new process, and as yet (1880) entirely done on hand-looms.

Tapestry carpets are yarn printed, which saves considerably in the cost, yielding the same durability.

MACHINERY USED IN SILK MANUFACTURE.

The silk industry of the United States does not exhibit, like many of the other productive industries in this country, an unbroken record of success. Though attempted early in the history of the British colonies—encouraged by the home government—it soon, however, failed when this support was removed. Again, when the craze for the silk-worm breeding, or rather the growing of the *Murus multicaulis*, spread over the country, and proved an ignominious failure, ridicule and mistrust were engendered and the progress of the industry checked. It is only lately, since encouragement has been afforded domestic manufactures by the tariff on imported luxuries, that the business has grown to considerable proportions, and is now one of the many industries the products of which Americans can rightly be proud of. The history of this industry convinces one of the fact that though machinery, improved and often invaluable, has done much toward producing the high quality and excellent appearance of the goods, yet the success of the industry, as a business, has devolved as much on question of general prosperity, supply and demand, government protection, and the dictates of fashion.

In many of the industries of this country, notably the utilization of the grain belt of the northwest, in the success of the American watch, steam-engine, rifle, etc., mechanical invention and improvement were the sole factors. In silk manufacture this is not quite as true; though of late years, especially in the near past, the machinery used in this industry is of great efficiency and mechanical ingenuity, yet the factors enumerated above have played an important part.

The general prosperity of the country is a great promoter of the silk manufacture. When every industry is depressed, and economy is the order of the day, all luxuries are discarded and as little silk worn and used as possible. When, however, the financial condition of the country again improves there is money to spend on comfort and luxury, besides the actual everyday needs. Silk, perhaps more than any other fabric, is dependent on such fluctuations of prosperity, as we can well dispense with it in our clothes and in our homes when wool and cotton are indispensable.

Another important consideration connected with the success of the industry is the question of government protection. Without the latter it would be impossible for domestic manufacturers, even with the most improved automatic machinery, to successfully compete with the hand labor of Europe, so patient, so skilled, and yet so little remunerated.

Success in some branches of trade, especially in its early days, was due in some cases to the fact that ocean freights were slow and uncertain, and domestic factories supplied a demand for a passing fashion before importers could bring the goods from Europe, or supply a lack of imports.

The dictates of fashion have not a little to do with the profit of the manufacturer. In trimmings and similar goods this factor prevents in some cases the use of other than general machines, as it would be a matter of considerable expense and ultimate loss for the manufacturer to build a machine specially applicable to a passing fancy. On looms for ribbons, piece goods, etc., this is not as serious a matter, owing to the applicability of these machines to various patterns, but in trimmings, a large and prosperous branch of the general business, hand labor has to be often used where machinery could be economically employed were the same design to remain for a protracted period.

Mechanical progress has had, however, a good share in assisting the industry in its advance to business success and the production of excellent materials.

Briefly enumerated, the chief mechanical features of a silk-mill are the appliances for twisting and doubling the reeled silk, treating the thread thus formed, and the weaving of the final product. The dyeing is invariably done in the yarn, with the exception of the cheaper class of handkerchiefs and similar goods, which are printed like calicoes.

Silk waste, or imperfect cocoons, the "short staple" of this industry, is also largely treated, and an extremely durable and excellent quality of goods manufactured therefrom.

As there are several thousand various mechanical appliances employed in this industry, it will be impossible to describe them all within the scope of a report of this nature. Mention will be confined, therefore, to a detail of the principal machines—those having a very prominent effect on the general efficiency of the mill. The figures and facts have been obtained from manufacturers and machinists, often widely differing, and not from personal experience or experiment. Before describing the processes and machinery it may be well to give a few historical points.

The only machinery used in the colonial days were, besides the reels in the filatures, common spinning-wheels, such as were used for cotton, flax, etc. About 1800 Horace Hanks introduced his double-wheel head. In 1829 Edmund Golding, a young Englishman, made designs of improved throwing machinery. About this time some improvement had also been made in looms and weaving machinery; and the industry having attained importance, a full description of the processes and machines may be found in the Rush letter, Ex. Docs. 158 and 226, Twentieth Congress, first session. In 1828 Toeshaven Bros. introduced a single machine for reeling, doubling, and twisting at once. This, however, has never been a success.

The next prominent inventor was Nathan Rixford, who in 1838 greatly improved that part of the process relating to throwing. In 1852 a great impetus was given the thread industry by the demand for machine twist, or silk thread appropriate for sewing-machines; and the improvement of the machinery has been rapid and large up to the present day. About 1855 the manufacture of silk goods from spun silk was begun at South Manchester, Connecticut, and necessitating an entirely different process, introduced a series of ingenious and efficient machines. However, up to this day much of this class of machinery is imported.

In 1868 the manufacture of silk nets was begun. A year later lace-machines were introduced, and in 1871 this branch of the industry was successfully begun in Brooklyn, the machinery for which is, however, almost entirely imported and of high cost.

PROCESSES.

Owing to the fact that silk is received in this country in two shapes, viz, "raw silk" or hanks of reeled cocoons, and "waste" or pierced, double, imperfect, etc., cocoons, there are two processes for the preparation of goods. We will first take up the reeled silk and its treatment as being the more widely spread branch of the industry.

The hanks of raw silk imported from Japan, China, and Europe vary in quality, owing to the greater or less care with which the thread was produced at the filature. Expert hands sort this silk and determine the portion to be made into tram or organzine (filling and warp). It is then soaked or washed, usually to remove any remaining gum and soften the fiber. The silk is then placed on winders and wound off on bobbins. Much simplicity is given the process by the fact that the raw material is a continuous thread, and hence the manifold and intricate appliances for reducing a mass of short threads into a thin sliver, as in cotton and wool, are dispensed with. The untwisted or dumb singles, as the filament is called, is doubled and twisted on spindles similarly to cotton yarn, this portion of the machinery being of especial excellence and efficiency. The twisted thread is then wound on reels into hanks and sized and dyed. The so-called throwing is twisting two singles already twisted separately, and usually in the opposite direction, to the final twist. For tram and organzine the threads are wound and again doubled after dyeing, and either warped into a beam or wound on a quill-winder for filling. Before and after these processes the thread is cleaned or cleared; that is, run over a machine which stops at every knot or imperfection, enabling the attendant to remove it. Another special process is the dramming or weighing of the yarn prior to dyeing.

The second, or silk-waste process, is one of considerable and growing importance. Though it has been operated at but a few points, yet the large mills and excellent product of Cheney Bros., at South Manchester, have proved the possibility of financial success in this line. Waste silk is not, as may be imagined, refuse or shoddy from silk-mills, but consists of imperfect, perforated, or otherwise injured cocoons, which cannot be reeled into a long, continuous thread. These, with the short staple produced at the filatures and in the subsequent treatment at the mills, form the raw material for this branch of the industry. A general outline of the process is as follows:

The waste is first washed, to remove the gum and leave the fibers clear and separate. It is then treated on the filling-machine, which is similar to a cotton-card, consisting of a cylinder upon which are set rows of pins which draw the fiber out from between two rollers. When the pins are full the silk is cut and placed between two pieces of board which open like a book. These are placed, several at a time, in the combing-machine, which combs first one side, then the other, and, removing all foreign matter, leaves the silk white and glossy, with all the fibers parallel. The boards are then opened, the flat piece of silk, with the fibers running crosswise, are rolled up and placed on the spreader. This beats the silk out to a flat band, which is then passed through gills on a blade and is rolled upon a cylinder. In this machine it receives its first continuous form. It is next taken to the sett, which is a similar gill contrivance, and reduces the sheet to about an inch in width. The process is then similar to that of other fibers. It passes through drawing-, doubling-, and spinning-frames until it becomes a fine thread. It is wound on bobbins and passed over a winder, upon which are small gas-jets which burn off any knots or lumps and give gloss to it. It is then reeled into hanks and dyed.

The application of this thread is manifold, part being sold for sewing and part being woven on looms into fabrics. Though at first the appearance of such spun-silk goods did not equal that of reeled silk, yet the present demand for cheap goods, such as handkerchiefs, etc., has enabled the establishment of a large business in this branch. The improved English machinery and care in the manufacture now enable the production of spun-silk goods of excellent appearance, almost impossible to discern from reeled silk, at much less cost and equal durability.

In all questions of silk cost it is the raw material that is expensive and which causes the high price of all silken fabrics; hence the advantage of spun silk, which, lacking little in beauty of reeled silk, is equally, and often owing to the absence of "weighting" more, durable.

The weaving of silk goods is done alost invariably on power-looms similar in every respect to those used for cotton, wool, etc. Only heavy black gros grain and other wide goods are still made on hand looms in Paterson, the principal silk manufacturing center of this country.

The Jacquard attachment for figured goods comes greatly into play in this industry. The possibility of weaving of figured handkerchiefs, labels, book-marks, and broader goods as yet depends on this ingenious contrivance, at least on power-looms. It is described in its present form in the succeeding pages. The warping

for the looms is done in many mills on a huge wooden cylinder, called the mill, from the bobbins. The resulting beams are combined together. Several establishments are running on rich goods of the damassé and other similar kinds, which are costly, but of excellent quality, and find a ready sale.

Velvets have been attempted, but do not amount to much in quantity of production as yet.

Trimmings form another important branch of the industry, and many appliances have been introduced to assist the skilled hand labor, which, however, is indispensable.

In general, silk machinery is somewhat simpler than that of the other textile manufactures, owing to the nature of the raw material. For the same reason more skilled labor and of a high class is needed, as the personal inspection and removal of imperfections is of paramount importance in the modern American silk-mill. Silk, owing to its smoothness and gloss, shows knots and imperfections to a greater extent than any other fabric; hence the utmost care must be taken with the thread before and during weaving, and hence the necessity of keen-eyed and skilled operatives. Another consideration is the fact that in this country, the machinery being all operated by power and automatic, the stoppage of a loom or other portion, resulting from an imperfection in the thread, is a matter of vexatious delay and financial loss, much more so than in Europe, where the machinery is operated by hand (looms), and hence can be stopped and started without great loss of time or money.

This feature of automatic treatment, and the consequent necessity of perfect thread in the weaving, is eminently a question brought out by the improved machinery used at present. In other words, the improved machinery has improved the yarn; the improved yarn has enabled power-weaving; and power-weaving, being at present almost absolutely the only way to produce the goods economically, has reciprocally caused a demand for the best thread, and hence has caused an improvement in the throwing, winding, doubling, and preparing machinery.

MACHINES.

As compared with cotton or wool machines silk machinery is of great simplicity, as reeled silk does not require the combination of short fibers into one long yarn, and later in the process obviating the drawing process necessary in the other two processes. Hence, after the preliminary operations previously alluded to the first machine in the

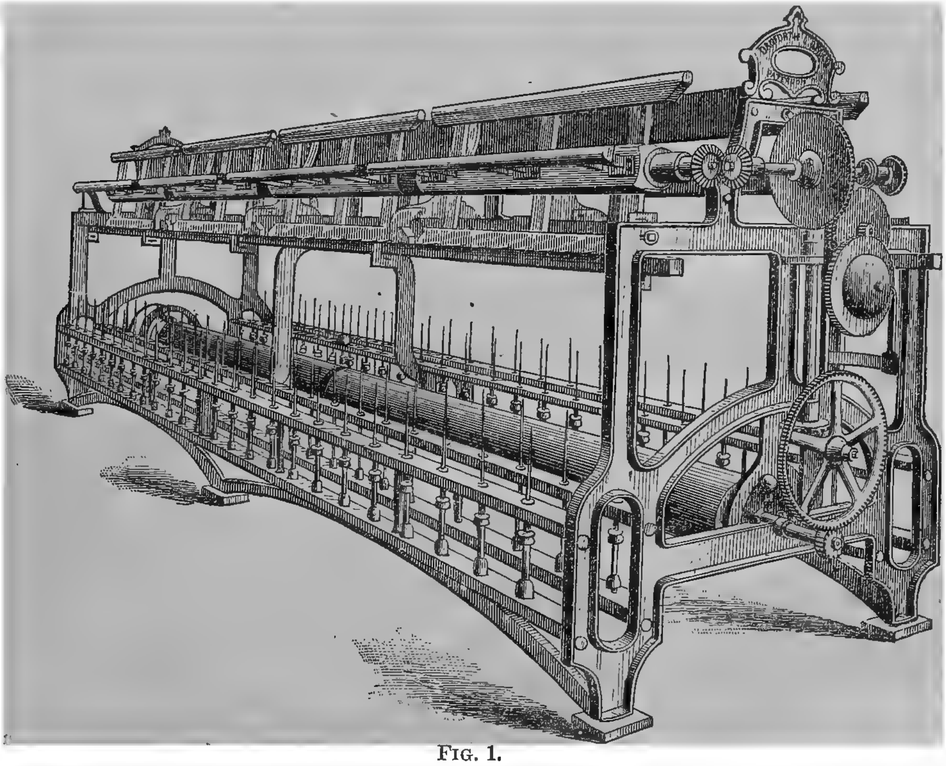


FIG. 1.

process is the winder. These machines are run at considerable speed; power required, about 600 spindles to a horse-power, the attendance being 5 girls to 24 spindles. The winding both of raw and soft silk have improved to a considerable extent. The reel-mill built by the Danforth machine-works, a machine for winding on skein, is shown in Fig. 1.

This machine takes about 1 horse-power to 300 spindles, and requires but little attendance. Doublers take 1 horse-power to 300 to 600 spindles, and about 6 girls to 100 spindles.

The most important machine previous to the loom is perhaps the spinning-frame. In this portion of the process much improvement has been effected, the spindles revolving at a higher velocity, more smoothly, and the whole size of the machine reduced considerably.

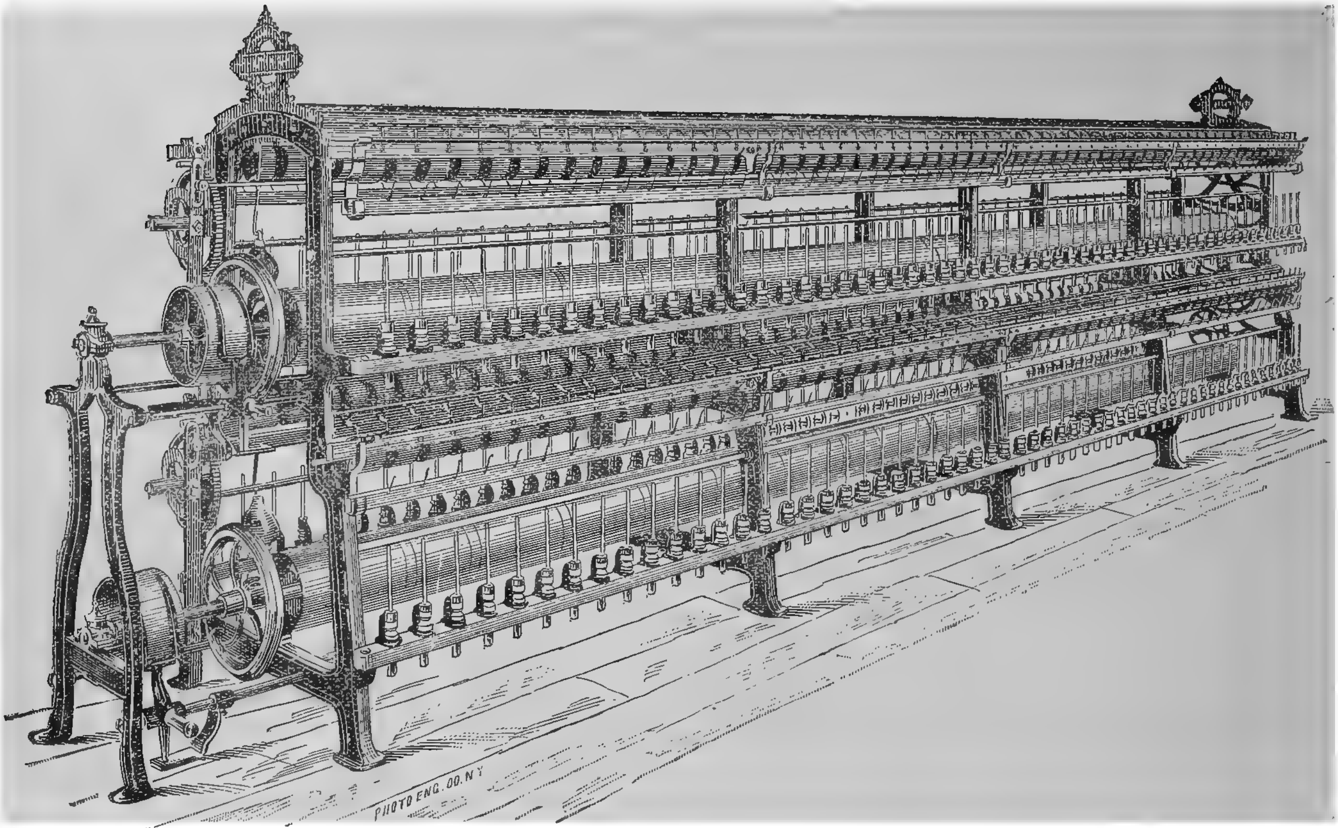


FIG. 2.

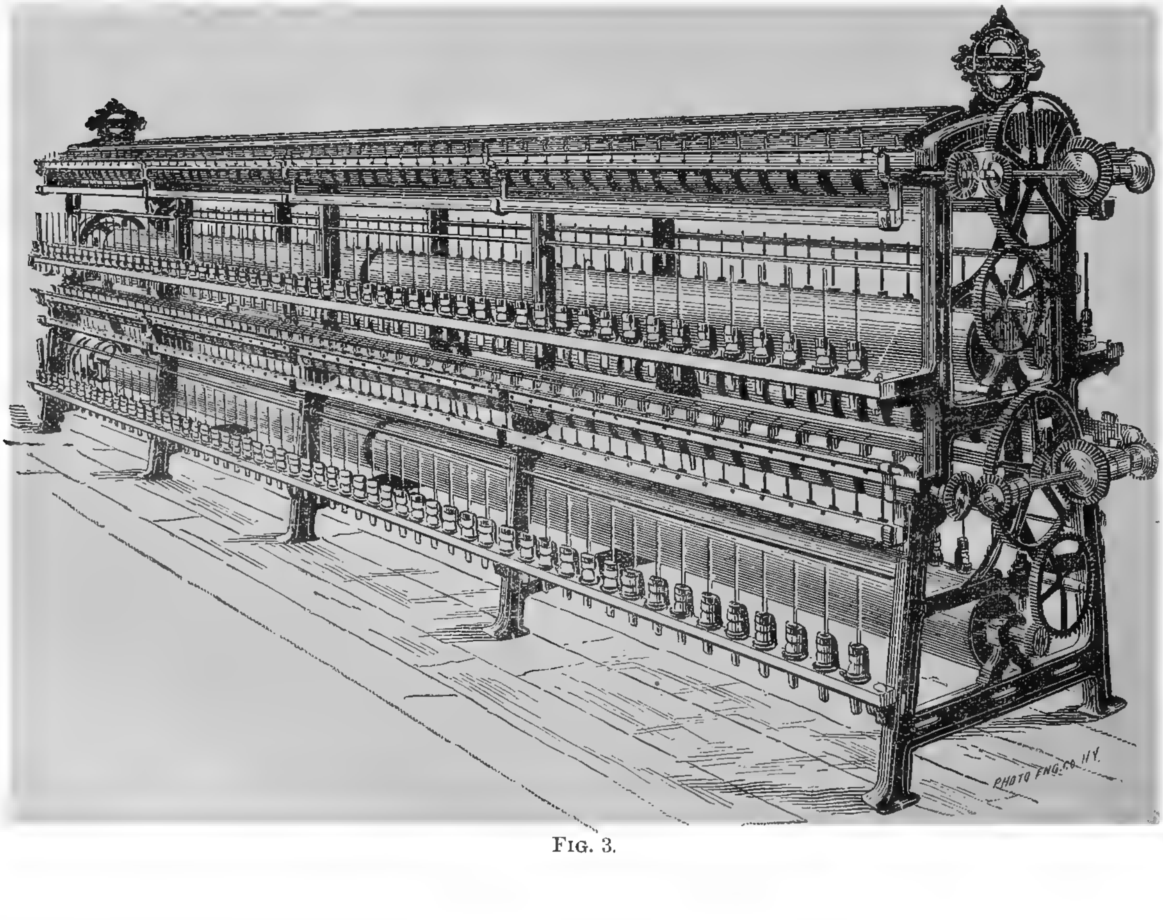


FIG. 3.

Figs. 2 and 3 represent the Danforth machine company's two-story spinning-frame, which is 32 inches between spindles, these being about 4 inches apart. It is estimated for spinning that $1\frac{1}{2}$ horse-power will run about 450 spindles, though of course the power varies, like in other similar machines, with the yarn to be twisted.

Fig. 4 represents the spindle used in the above frame. Fig. A is an elevation, and Fig. B section. B is the spindle; D the sleeve, which insures its rigidity; P the step; G the rail. It will be seen that there is but one rail,

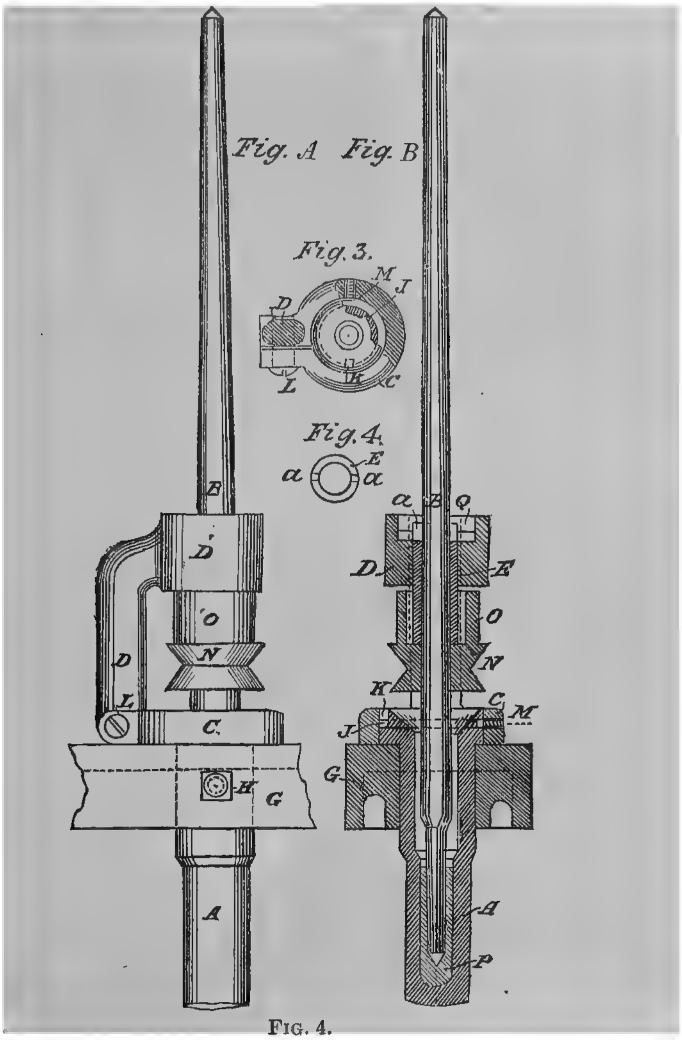


Fig. 4.

the bracket and sleeve D taking the part of the upper rail. This has enabled the reduction of the mill by 12 inches in width; an economy of ground space. N is the pulley. The spindle is a self-oiler, and no oil can escape by centrifugal force, as may be seen from the figure.

The gearing of the frame insures immunity from belt slippage, and though the width is thereby somewhat increased, the gearing shown in Figs. A and B is simple, and by far more direct than in the very narrow spinning-frames, which have been built but 10 inches wide.

At present silk machinery is run at very high speeds, and spindles and other rapidly revolving parts have attained high proficiency. At a speed of 10,000 revolutions per minute the modern spindle moves as smoothly and with no slopping or heating as one ten years ago running at a quarter of this speed. The improvement in this branch, parallel with that in cotton-spindles, has been very rapid the past few years.

Fig. 5 represents a quill-winder, or machine for winding the weft or the small bobbin of the shuttle. Formerly these were quills, whence the name, but owing to the high cost other materials are at present used. This machine takes the place of the more cumbersome winders used for cotton and wool, where the filling is wound on heavy bobbins. The machine takes but an insignificant amount of power and but little attendance, excepting replacing the filled quills.

Silk, especially in this country, is manufactured in greater part into figured goods; hence the necessity of looms capable of producing every variety of design. Probably there are more Jacquard attachments in proportion to the number of looms in silk than in any other textile industry, as this contrivance permits of a greater variety of designs than the common fancy loom.

The Jacquard attachment to a loom, now applied to looms with several shuttles and lately to positive-motion looms with a species of let-off motion to the shuttle for weaving goods not in a plane, is described here for

the above reason, though it is applied to woolen and other textile manufacture to a considerable extent. The object of the contrivance is to automatically select certain threads of the warp and raise them above the shuttle as it passes through the shed thus formed, to raise the same threads at the end of each series of variations, and to keep this process up *ad infinitum*. The machine now so extensively used was the invention of the Lyonais whose name it bears, and who, unlike other useful inventors, was well remunerated by his government.

The principle of the machine is as follows: The warp threads pass through the usual heddle arrangement;

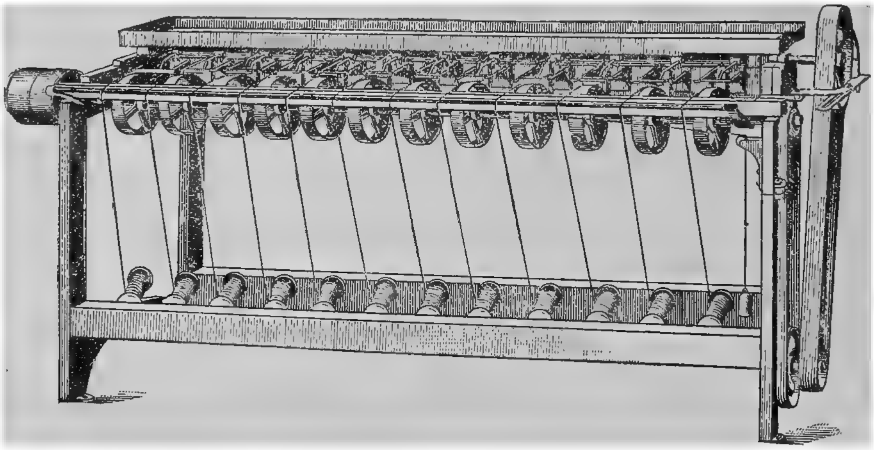


Fig. 5.

the tops of these are, however, separate, each warp thread being thus independent of the others. To the tops of these heddles, which are really lifting-bars, short bars are hooked on. These are called needles. Around them are wound coiled springs, which continually press upon them. Opposite the heads of the needles is a prismatic box, containing holes on its sides exactly opposite the needles, so that these slip in, impelled by the springs. If, however, one of the holes be closed, that needle will not be raised. To raisé certain threads and leave the others unmoved a series a card-board rectangles, hinged together at the edges, is run over the prismatic box. Through these are punched holes corresponding to the needles to be raised. Where a hole is punched it coincides with the hole in the box the needle enters, and the thread is lifted. Similarly, if the hole in the box is covered by the card-board, the needle is held and prevented from raising the thread.

Figs. 6, 7, and 8, from Appleton's *Cyclopedia of Applied Mechanics*, show the construction of the machine. It has been greatly improved lately. Some have been manufactured of such weight as to require sheet-iron cards. By detail improvements it is probable that the best Jacquard has an increased efficiency and speed of at least 20 per cent.

The following figures show the construction which, owing to the necessary mechanical motions in connection with the loom, is somewhat complicated:

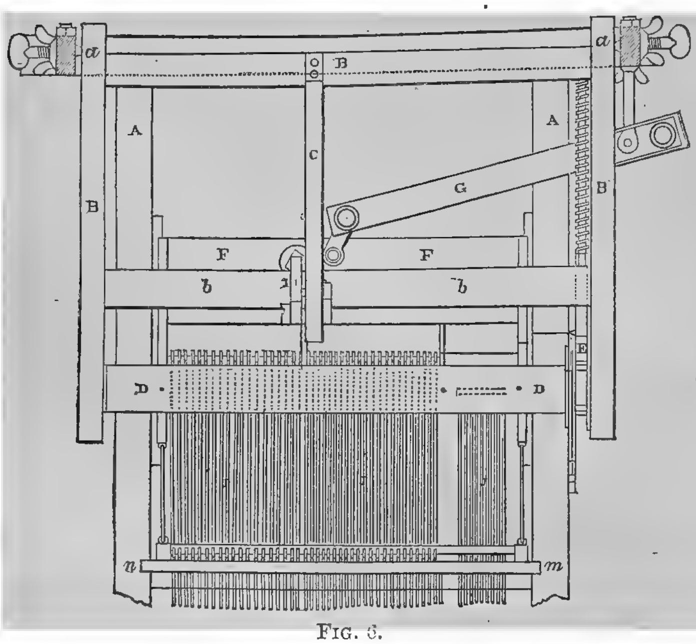


Fig. 6.

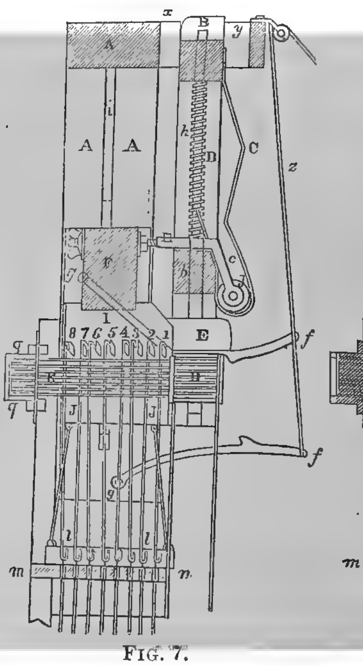


Fig. 7.

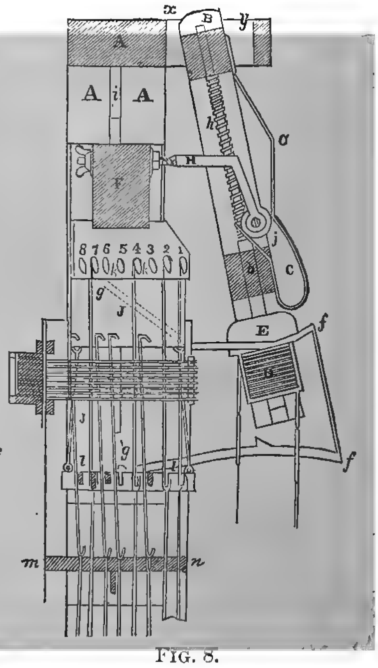


Fig. 8.

These letters are the same in the three figures. A is the frame of the machine; B an auxiliary frame which vibrates about B. Fig. 7 represents the warp lowered, and Fig. 8 when the warp is raised. D is the prismatic

box, on which the chain of cards rotates. K K are a system of pins or needles, which are pressed by spiral springs *a a* against the box D and the card upon it. J J are the rising-bars or hooks, which are connected with the heddle-threads (these latter being greatly prolonged) shown at T. 1, 2, 3, 4, 5, 6, 7, 8 are catch-pins, which are fixed in the frame F, this latter having an up and down motion, and thus raising the bars J J when these are caught by their upper hooks on the pins 1, 2, 3, etc. The other motions are visible from the cuts.

The operation of the machine is as follows: When the appropriate card comes on the box the pins K K, that are opposite holes in the card, are pressed in, and draw the hooks J J on the catch-pins 1, 2, 3, etc. The other pins, J J, are kept back, and when the frame F rises, only those hooks are raised that are connected with the needles that have entered holes.

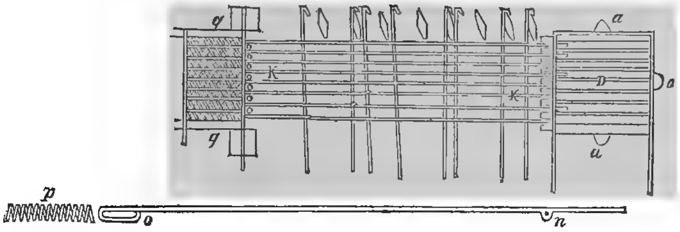


FIG. 9.

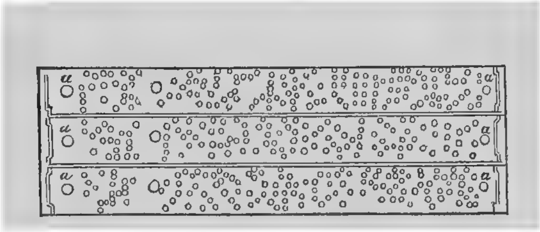


FIG. 10.

Fig. 9 shows the construction of the needles; *n* is the eye with which it connects with the bars J J.

Fig. 10 shows the appearance of the cards. It is evident that the imperfections of the machine are considerable—complicated, delicate machinery, and hence a liability to derangement; considerable difficulty in punching the cards properly. In many cases a very large number of cards are necessary, some designs needing up to 25,000 cards (portraits, book-marks, etc.). Hence the advantage of fancy looms when their use is possible. On very heavy looms sheet-iron cards have been used, but this is unnecessary in silk manufacture. The application of this contrivance to looms is shown in the following examples. At present the frame of the Jacquard is all of iron.

Fig. 11 represents Uhlinger's Jacquard loom. As will be seen from the cut, it is a plain picking-stick loom

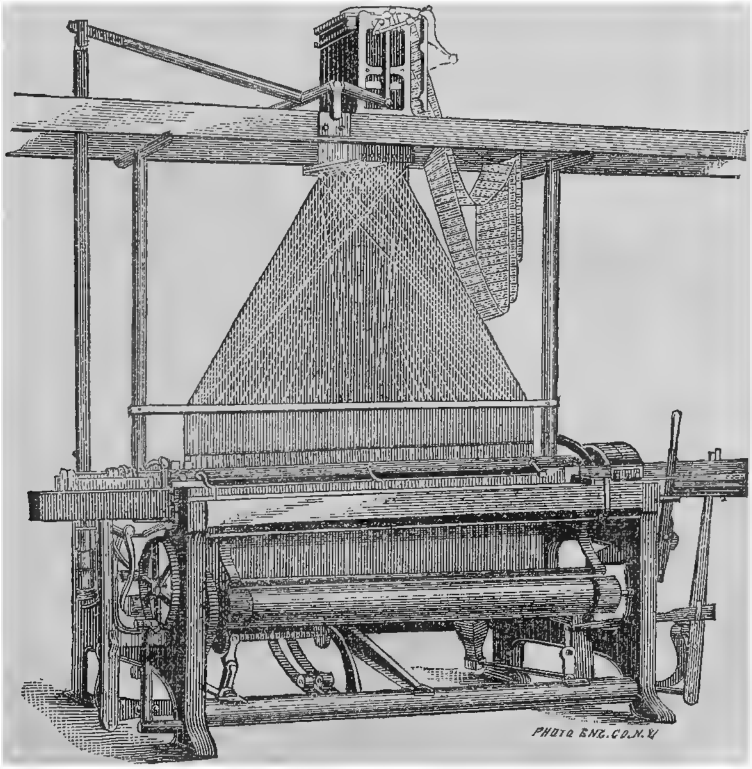


FIG. 11.

with a Jacquard attachment on a frame above. This is the general style of silk-loom for figured goods, and is an example of the greater part of power silk-looms operating on this class of goods.

Fig. 12 represents a loom for ribbons. This is the so-called gang-loom, the shuttles being operated by a rack-and-pinion motion, their stroke being very short, ribbons alone being woven on these machines. There are 2 Jacquards for each machine and 4 shuttles. The ribbon is wound upon the rollers shown, and the take-up motion is a simple gear contrivance.

Fig. 13 is a similar loom, but without Jacquard, being arranged with chain and harness. It is built by Knowles & Brother. It is a rack-and-pinion loom, the shuttles having but a very short travel. The take-up motion is very

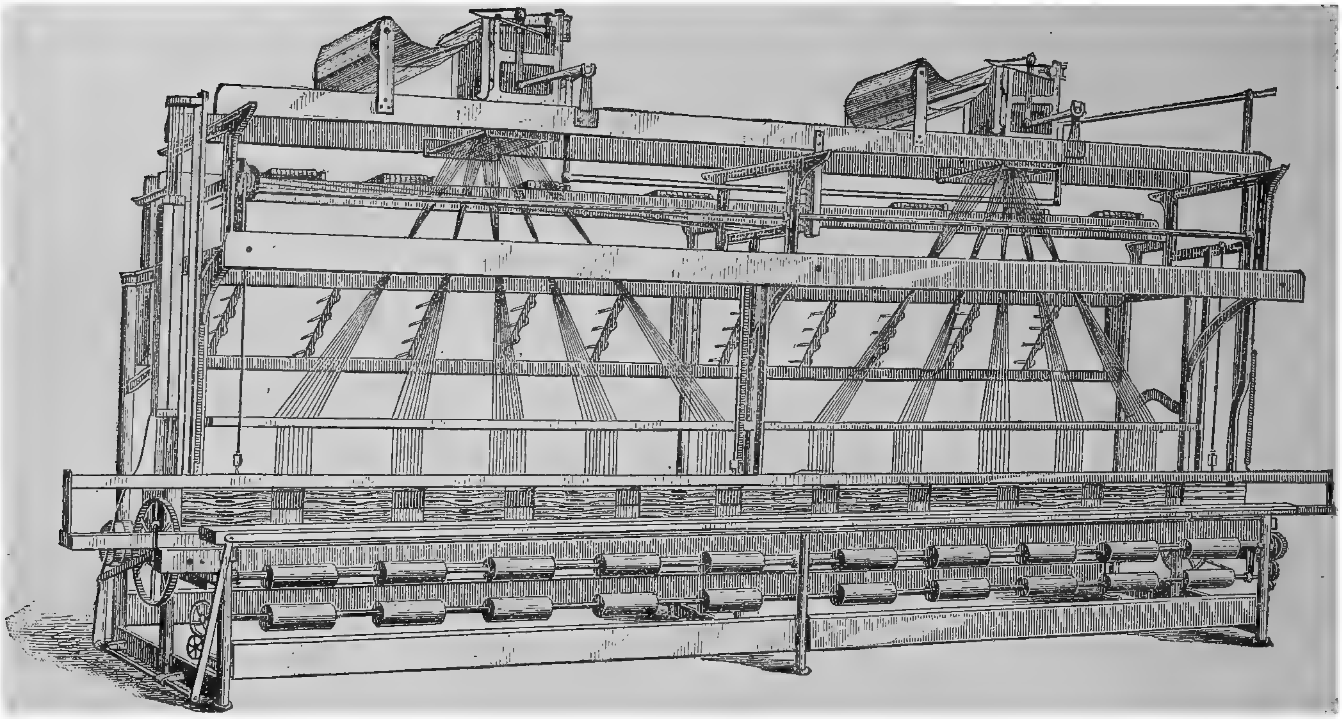


Fig. 12.

simple, similar to the one in the previous loom, and clearly shown in the cut. The advantage of Knowles' other looms is also present in this machine, viz, the possibility of detaching the design, forming machinery, and operating it alone by hand in case of misspicks.

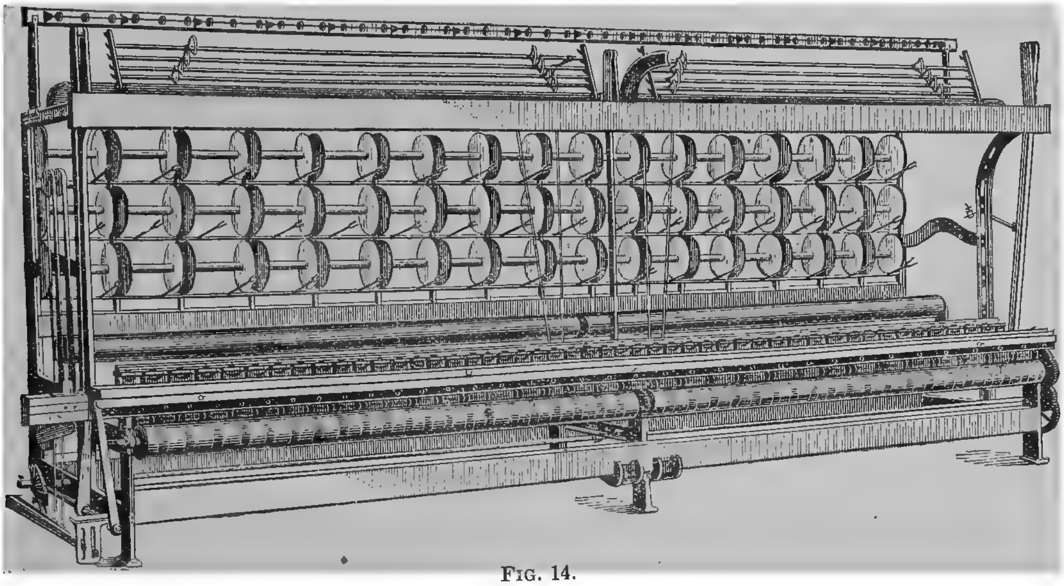


FIG. 14.

Fig. 14 is an extra narrow loom for stay bindings, silk braids, and similar materials. It is built by Uhlinger. The movements are similar to those in the ribbon-loom. It is given as an example of the extreme of the gang-loom.

INDEX TO WOOL AND SILK MACHINERY.

REPORT

ON THE

MANUFACTURE OF ENGINES AND BOILERS,

WITH

A REVIEW OF THE PRINCIPAL TYPES

OF

ENGINES FOR MANUFACTURING PURPOSES,

BY

CHARLES H. FITCH, D. E.,
SPECIAL AGENT.

TABLE OF CONTENTS.

LIST OF ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

NEW HAVEN, CONNECTICUT, *October* 1, 1881.

Prof. WILLIAM P. TROWBRIDGE,

Chief Special Agent:

SIR: The report herewith submitted presents an outline of a very large subject. It deals rather more fully with the economy of manufacture than with the types and uses of engines and boilers. The statistics of the use of power are prepared and reported upon by others, and this fact precludes their consideration here.

The merits of the different types of engines are well understood, but they have not here been very closely compared, for although reports of trials and tests in great numbers are available, their results are not considered finally decisive of the merits of peculiar features. In close competition in economy trials the differences shown are often due to proportions and running condition no less than to unique design, and despite the high results obtained in trials, there is great room for improvement in the economy of ordinary practice even in those sections of the country in which it is of the highest financial consequence.

Economy of manufacture is a consideration of high importance and deserving comprehensive study.

Every slight improvement in machinery, or in system, requires greater intelligence in management, and produces better results, registering a sustained advance both in intellectual power and in material wealth.

Respectfully,

CHARLES H. FITCH,

Special Agent.

STATISTICS OF THE MANUFACTURE.

The manufacture of steam engines and boilers in the United States.

States and territories.	Number of establishments.	Capital.	Greatest number of hands employed at any one time during the year.	AVERAGE NUMBER OF HANDS EMPLOYED. Males above 16 years.	Females above 15 years.	Children and youth.	WAGES AND HOURS OF LABOR. No. of hours in the ordinary day of labor. May to November.	November to May.	Average day's wages for a skilled mechanic.	Average day's wages for an ordinary laborer.	Total amount paid in wages during the year.	Materials.	Products.
The United States ..	462	$24, 739, 336	29, 843	23, 504	4	628	10	10	$2 35	$1 25	$11, 469, 249	$20, 021, 249	$38, 221, 636
Alabama	3	24, 000	57	43	....	5	10	10	3 00	1 00	18, 100	14, 000	38, 000
California	26	915, 450	1, 167	883	....	15	10	9	3 30	1 95	522, 590	856, 822	1, 635, 898
Colorado	1	15, 000	24	21	....	3	10	9	3 00	2 50	15, 600	60, 600	100, 000
Connecticut	12	281, 625	478	372	....	8	10	10	2 45	1 40	180, 413	387, 667	665, 671
Delaware	4	1, 465, 000	1, 407	1, 279	....	19	10	10	2 50	1 00	608, 512	1, 868, 876	2, 848, 825
Georgia	1	112, 344	119	113	....	6	10	10	2 50	75	34, 822	27, 332	82, 179
Illinois	20	667, 700	1, 219	940	....	44	10	10	2 50	1 35	472, 790	1, 092, 800	1, 808, 378
Indiana	17	1, 110, 500	1, 518	1, 437	....	27	10	9	2 15	1 30	605, 115	2, 122, 700	3, 051, 325
Iowa	7	75, 500	137	94	....	2	10	10	2 45	1 40	49, 700	69, 668	175, 712
Kansas	3	90, 200	95	79	....	....	10	9	2 60	1 35	49, 469	36, 868	114, 000
Kentucky	14	362, 600	428	349	....	9	10	10	2 40	1 25	158, 450	245, 573	516, 991
Louisiana	7	22, 250	91	42	....	5	10	10	3 30	1 45	20, 050	26, 500	64, 000
Maine	2	30, 000	45	29	....	....	10	10	2 10	1 35	13, 800	18, 500	39, 900
Maryland	10	602, 000	919	707	....	11	10	9	2 15	1 20	390, 000	433, 925	957, 775
Massachusetts	18	1, 271, 000	1, 061	905	....	9	10	10	2 50	1 45	494, 345	1, 108, 316	1, 919, 951
Michigan	21	1, 203, 550	1, 225	892	....	51	10	10	2 15	1 25	409, 564	660, 442	1, 464, 234
Minnesota	4	24, 450	107	86	....	....	10	10	2 60	1 55	52, 800	87, 000	170, 000
Mississippi	2	5, 500	24	24	....	....	10	10	4 50	2 35	19, 335	11, 000	38, 000
Missouri	13	458, 250	858	780	....	....	10	9	2 50	1 40	358, 014	504, 887	1, 034, 067
New Hampshire	2	220, 000	228	161	....	43	10	10	2 00	1 20	86, 335	145, 486	286, 400
New Jersey	21	415, 300	694	587	....	6	10	10	2 15	1 00	289, 331	385, 057	812, 919
New York	69	4, 660, 975	6, 594	4, 431	3	133	10	10	2 25	1 30	2, 393, 716	2, 481, 349	6, 022, 973
North Carolina	1	2, 000	12	7	....	....	11	10	2 25	1 00	3, 500	700	6, 000
Ohio	43	2, 623, 950	2, 614	2, 250	....	37	10	9	2 25	1 25	938, 357	1, 642, 142	3, 373, 091
Oregon	7	156, 500	202	116	....	6	10	10	2 50	2 00	102, 484	81, 397	237, 200
Pennsylvania	89	5, 665, 792	5, 594	4, 512	....	128	10	10	2 20	1 20	2, 030, 595	4, 056, 718	7, 308, 283
Rhode Island	5	795, 000	777	653	....	2	10	10	2 30	1 30	356, 588	378, 110	932, 252
South Carolina	1	30, 000	40	35	....	3	10	10	2 50	50	10, 000	10, 000	40, 000
Tennessee	8	99, 100	231	160	....	6	10	10	2 50	1 05	65, 376	97, 574	250, 525
Texas	2	7, 500	24	12	....	4	10	10	3 10	1 65	8, 500	10, 000	27, 000
Utah	1	15, 000	6	1	....	1	10	10	3 50	1 00	780	2, 100	3, 840
Vermont	4	267, 100	158	143	1	....	10	10	2 10	1 35	57, 828	74, 241	171, 328
Virginia	8	254, 700	577	463	....	30	10	10	2 10	1 10	172, 726	259, 150	538, 956
West Virginia	4	42, 000	118	82	....	1	10	10	2 25	1 15	38, 800	25, 871	74, 762
Wisconsin	12	747, 500	995	816	....	14	10	9	2 35	1 30	440, 864	737, 878	1, 411, 201

SIZE OF SHOPS IN ENGINE-BUILDING.—There are three classes of establishments which merit consideration in respect to engine-building. In the first the manufacture is pursued in connection with boiler-making, which often constitutes a large portion of the work. In the second it is a manufacture solely of engines and kindred

machinery. In the third we have a small class of factories whose facilities are exclusively devoted to the production of the smaller engine parts, such as governors and valves. Of the two first classes we make the following comparisons by size of shops rated in average numbers of operatives. These figures are the averages for all the shops of the kind in the United States excepting a few in which the work is of a special or involved character:

Engines and boilers.

Operatives in shops.	PER OPERATIVE.			
	Product.	Capital.	Material.	Labor.
100 and over	$1,584	$813	$897	$438
50 to 100	1,562	1,324	720	470
10 to 50	1,535	979	698	469
Less than 10	2,150	863	1,095	510

The increments of value of product above material are $687, $842, $837, and $1,055 for the several classes in the order stated.

Engines and machinery.

Operatives in shop.	PER OPERATIVE.			
	Product.	Capital.	Material.	Labor.
100 and over	$1,365	$951	$652	$504
50 to 100	1,275	1,256	495	465
10 to 50	1,355	1,001	592	432
Less than 10	1,509	1,278	595	477

The increments of value of product above material are $713, $780, $763, and $914 for the several classes in the order stated.

The following comparison is also made between factories engaged in the manufacture of steam-valves, steam-gauges, and governors:

	PER OPERATIVE.			
	Product.	Capital.	Material.	Labor.
Steam-gauges	$1,638	$1,255	$729	$519
Steam-valves	2,520	3,249	1,337	468
Governors	1,589	1,105	674	444

In the manufacture of governors we have an example of the manufacture of small iron parts; in gauges and valves more generally of small brass parts. The small iron work requires less capital and has a smaller value of material and product per operative than the brass work. The manufacture of steam-gauges is a finer class of work than the manufacture of steam-valves. This is exhibited in the relative costs of labor, and in the fact that the value of material is increased about 55 per cent. in the former against 47 per cent. in the latter process of manufacture. The manufacture of steam-valves is a more highly organized work, employing large capital, and enabling much larger quantities of material to be handled per operative than that of steam-gauges.

The manufacture of engines and boilers together may be expected to present some extremes of comparison as one or the other of these two classes of work preponderates. The largest shops (100 operatives and over) present a small showing of capital per operative, whether compared with shops of similar size in boiler-making or in the next class of engine- and boiler-making taken together. It may be said that engine-building usually requires a heavier investment in real estate and machine plant than boiler-making, while when both manufactures are united in one system a large and expensive establishment is inevitable. Such an establishment with a double purpose costs relatively more in investment per operative for a small than for a large number of operatives. But the statistics do not necessarily indicate any such industrial cause, because there are certain variations in the returns of capital which seem scarcely warranted by any basis of comparison. Thus for the largest class of works we find the capital per operative ranging in engine-building from $166 to $3,350, in engine- and boiler-making from $125 to $1,818, and in boiler-making from $200 to $1,500. These are the returns as made, but such extreme figures are exceptional in the returns.

In the class of work represented by shops with less than ten operatives each, jobbing, repairs, and general mill-work have a large influence. The cost of labor is therefore high, a much greater increment of value is given to

the materials, and the product per operative is of much higher value than in any other class. Doubtless the value of the product in engines and boilers per operative for the first class, $1,584, represents in quality and quantity much more machinery than the greater value per operative for the fourth class, $2,150. The higher valuation of job work and of work in small shops remote from manufacturing centers exercises upon the financial statistics an influence similar to that of the most effective work and the highest output for the labor in the large shops. The small shops are so much scattered and have so little uniformity of work that there is no strong competition, while the large shops, depending often upon remote markets, are in active competition, which tends to reduce the valuation of the product.

SIZE OF SHOPS IN BOILER-MAKING.—In a comparison of a large number of shops rated by numbers of operatives we obtain the following figures per operative:

Operatives in shop.	PER OPERATIVE.			
	Product.	Capital.	Material.	Labor.
100 and over	$2, 770	$1, 253	$1, 856	$425
50 to 100	1, 248	516	618	424
10 to 50	1, 708	735	1, 026	431
Less than 10	1, 849	707	857	480

So far as size of boiler-shop is concerned, these figures seem robbed of significance by the preponderance of other considerations, viz, locality, quality and size of work. It would appear that only in shops of the largest size do the increased product and capital and the material handled per operative stand out in spite of considerations other than size of shop. In the above averages the increments of value of product above material are $914, $630, $682, and $992 for the several classes in the order stated.

A few words will explain any apparent inconsistency in the order of the figures. Something of this is due to locality. Values are upon a sliding scale for the different sections. Nominally labor costs least in the middle states, Maryland, Virginia, Indiana, and Ohio. In New England it is rated higher, and in the west ranges still higher, being highest in California and in the sections of the south and west remote from centers for the manufacture of machinery. Coal is cheapest in Pennsylvania, West Virginia, Missouri, Kentucky, Ohio, Indiana, Tennessee, Delaware, New Jersey, Maryland, Virginia, and New York, about in that order. As compared with its cost in Pennsylvania we may say roundly that it is more than doubled in Massachusetts, trebled in Minnesota and Alabama, and more than quadrupled in California, that is, taking averages of the iron manufacturing sections of entire states for comparison. The cost of iron is determined less by geographical position than by commercial demand. Its cost of transportation for the same value of material being small as compared with coal, its cost usually varies only a few dollars a ton for all large manufacturing centers from Boston to San Francisco.

Boiler-shops, with fewer than 10 operatives each, will chiefly be found remote from large manufacturing sections. Labor is costly in two senses, both in the nominal rate charged and in the inefficiency of its application, there being, since competition is sluggish, little incentive to obtain the most economical results. Here, then, we find the cost of labor a large element of the value of the product. Materials are also expensive, but as much of the work is in jobbing and repairs, the cost of new materials appears relatively small. The investment may be intrinsically small, but high rates of interest, coupled with the imperfect and partial employment of facilities, causes the latter to appear costly when compared with the value of the product. For the same product per operative the cost of facilities is nearly double that in the average of the larger shops.

In boiler-shops with from 10 to 50 operatives labor is both nominally less in cost and more advantageously applied. The skilled labor is often of a higher grade, but more common labor is utilized. The work is more continuous, less of it is in repairs, and a greater value of material is employed, but the falling off in the cost of facilities per operative is so great as to cause a falling off in the gross value of the product per operative.

In boiler-shops with from 50 to 100 operatives, labor costs still less, but the advantage is due to the better disposition of large bodies of workmen rather than to the introduction of costly labor-saving facilities. The cost of material handled per operative is relatively small. This appears anomalous, but the number of shops averaged is comparatively small, and a number of these are occupied in the manufacture of small boilers and heaters and variety work involving castings. The average grade of the work in this class is lower than the general average of boiler work, there being, per operative, less capital investment, less expensive facilities, less cost of material, and less cost of labor, all indicating a small class of work.

In the largest boiler-shops, of over 100 operatives each, the facilities are much more costly. They are adapted to handle large work rapidly, and the cost of material handled, per operative, is much greater than in the smaller shops. They are adapted to save skilled labor, and although some labor of the highest skill is employed, these facilities, as well as the necessity of a larger proportion of common labor to move and handle the heavier work, operate to reduce the average of wages paid. The product per operative is greater than in the smaller shops, and

ENGINES AND BOILERS,

Compiled from Tenth Census.

Maximum number of Operatives for each locality, not inclusive of Railroad Shops, and a considerable indeterminate number inseparable from other machine work.

exclusive of returns of work for repairs, the increased value given to the material is greater per operative than in the small shops. This is simply due to the employment of the larger investments of capital necessary in handling heavy work.

While if the work were of a uniform character for all sizes of shops we might expect a steady gradation of the industrial factors, each class cited does in fact present most strongly a special character of work: the smallest, repairs; the second, medium; the third, light, and the fourth the heaviest work.

DISTRIBUTION OF ENGINE- AND BOILER-SHOPS.

REMARKS ON THE MAP.—The number of operatives employed is of course no exact criterion of the product, but may serve to indicate it in a general way. It should be borne in mind that the important manufacture of locomotives (with the work of locomotive repair shops) and of steam fire engines and pumps are not included in the figures, but it is inevitable that the manufacture of machinery in connection with engines should be more or less included. In a few cases, where engine-building is associated with ship- and bridge-building, an effort has been made to separate by estimate the proportions of the distinctive kinds of work, these being so far merged in the actual economy of the business that only estimates are available.

While we may see from the map how notably the manufacture of engines and boilers indicates the place and the importance of general manufacturing interests, in each section the manufacture has its predominant characteristics which deserve to be noted.

In New England the manufacture of engines and engine parts predominates, and it is estimated that six-tenths of the whole number of operatives are engaged in this work against four-tenths engaged in boiler work. In Boston, especially, the manufacture of governors, valves, gauges and other small parts which go to make up a steam-engine, is pursued as a distinct industry. New England may also be esteemed the birthplace of the automatic cut-off engine, and this class of engines, of fine workmanship and large powers, constitute the greatest item of the manufacture. Farm and portable engines are manufactured, although the small and hilly farms of this section do not permit the extensive use of the former, and this product is shipped mainly to the south. In boiler-making, a considerable and increasing proportion of the product is applied in steam heating rather than for steam power.

In the middle states we may consider that nearly two-thirds of the operatives are engaged in boiler work. In New York city the greater part of the operatives work at marine engines and boilers, and their repairs—no small item—since over one-sixth of the steam tonnage of the country is inspected at this port, and the foreign commerce is even in greater proportion. In Philadelphia, the manufacture of locomotives, not here included, employs a large number of operatives.

The manufacture of marine engines and boilers, with their repairs, constitutes the chief factor of the work along the seaboard as far south as Norfolk, Virginia, while on the great lakes the heaviest part of this work is done at Cleveland, Ohio; Erie, Pennsylvania; Buffalo, New York, and Detroit, Michigan.

The manufacture of automatic engines is pursued by large works in the middle states and in the west, but in the west and south, and especially in the great grain and lumber states, farm engines and portables constitute the largest item of manufacture, and large numbers of plain slide-valve engines are built. In the west the prominence of the industry in a few localities is to be noted as an evidence of the rapid growth of the country and of the great demands of the surrounding sections. In the south, Richmond, Virginia, is the great center for the manufacture of portable and agricultural engines.

Of the great amount of steam power employed upon the Mississippi river and its tributaries, the supply of machinery is maintained mainly at Pittsburgh, Pennsylvania; Cincinnati, Ohio; Louisville, Kentucky, and Saint Louis, Missouri. River and marine service is usually more exacting than land service, and a greater proportion of the work is required in repairs, especially of boilers. Thus, boiler- and repair-shops are found established all along the navigable waters, and it should be noted that many of these rivers are not shown upon the small-scale map. Boiler-making may be considered the pioneer industry. This, with the repairs of river engines, may warrant the establishment of a shop remote from large manufacturing centers. Then, when the surrounding country develops the demand, there is already established a small nucleus of skilled labor and facilities for entering upon the manufacture of farm and saw-mill engines.

In the New England, the middle, and the more populous western states, the division of the industry is notable, engines and boilers being built in separate shops and under separate management, and separate factories existing for the manufacture of the smaller parts. This is distinct from the practice of small shops along the river courses in which boiler-making, with engine repairs, is the rule, because the demand does not warrant shops large enough to invest in facilities for the general manufacture of engines. Then, between the two kinds of work there is a great cementing bond in the manufacture of portable engines, in which boilers and engines being assembled together are usually manufactured under one management. While small portable engines are turned out in quantities with uniform parts, as we might say, almost like pistols, it is obvious that in the manufacture of the largest blowing, pumping, and marine engines no such methods are available. In these the work is done by special contract from the designs of special engineering skill.

In the southwest (the Mississippi valley) and upon the Pacific coast the manufacture of boilers occupies nearly seven-tenths of the whole number of operatives. This is largely due to the fact that the marine engines employed are to a great extent manufactured on the Atlantic seaboard for the Pacific service, and at Pittsburgh, Cincinnati, and other northern river points for the whole Mississippi valley. But in the northwest, the manufacture of steam-engines being inevitably associated with that of farm, sawing, and milling machinery, the proportion of boiler work appears relatively smaller, averaging perhaps 40 or 50 per cent. of all, rating by numbers of operatives employed.

LABOR.

CALCULATION OF PERCENTAGE OF SKILLED LABOR.—A rule has been employed in deriving the percentage of skilled men in the industry as follows:

A being the average daily wages for all, that is the wages paid in a year divided by the average number of men employed and by 300, B the stated wages per day for skilled, and C for unskilled labor, and x the percentage of skilled men, then $100\ A = Bx + C(100 - x)$ and

$$x = 100 \frac{A - C}{B - C}$$

whence we have the rule: Deduct the wages for unskilled from the wages for skilled labor and from the average daily wages, and divide 100 times the latter remainder by the former. Three hundred days are taken instead of 313 to compensate in some degree for lost time not returned.

The results obtained are of interest, but not entirely conclusive. In the returns the time is sometimes stated as short, and the average number of hands is given for the running time only, and not for the full year, nor with any reduction of average on account of lost time.

REPORTED TIME OF LABOR.—In the majority of the states either full time or an average of over 99 per cent. of full time is returned, the percentages being rated not by factories but by numbers of operatives. In the remainder the averages are about—

	Per cent.		Per cent.
Connecticut	91	Missouri	95
Pennsylvania	97	Kansas	97
Maryland	98	Ohio	95
North Carolina	87	Indiana	97
Mississippi	80	Illinois	98
Louisiana	93	Iowa	95
Kentucky	96	Colorado	86

A SOURCE OF ERROR.—Some cases are not fair criteria on account of the average number of operatives being overstated. The statements returned for average numbers of operatives are rough approximations, the numbers of hands employed varying from time to time. It is to be expected that they will not always be consistent with the stated time and daily wages paid. Shops which run full time the year around often have for a time a short number of hands on account of break-downs, changes, repairs, strikes, short orders, severe weather, sickness of men, and the like, and the proprietor has not often the averages of these changes calculated to a nicety to return to the census agent. In like manner piece-work and overtime-work (paid perhaps at increased wages) may disturb averages based on regular full time. The tendency being mainly in one direction, error is not eliminated in the larger averages.

The usual tendency of manufacturers in making returns is not to shrink the apparent size of their establishments by allowances for temporary and partial stoppages. There is a certain pride in the employment of a large number of men, and the general average is belived to be over- rather than under-stated, so that the average wages deduced from the statements of average numbers of hands and wages paid will usually be found lower than the actual average wages. This is conspicuously the case in some individual returns of engine- and boiler-works, and doubtless has great effect upon the general showing.

THE PERCENTAGE OF SKILLED LABOR.—The apparent percentage of skilled labor in engine-building and boiler-making calculated by the rule explained, averages for the New England and middle states about 40 per cent., for the southern and western states about 30 per cent., and in the states and territories of the far west about 36 per cent. In some of the southern seaboard states this apparent percentage appears quite low, but it is higher in the southern inland states. In some of the large grain states it is also low, but is as high as 47 per cent. in two of the northwestern states, a percentage exceeded in seven other states and territories, Kentucky, Kansas, Utah, Maryland, Rhode Island, New York, and Oregon.

Average percentages of skilled labor appear ranging from 74 per cent. downward for the several states. The general apparent average is about one-third. In the large engine factories of Rhode Island the average appears at 51 per cent., in those of New York at 48 per cent., and of Wisconsin at 47 per cent.

Three conclusions are very obvious in this connection: First, that the percentage of skilled or highly-paid work is usually greater in engine-building than in boiler-making; second, that it is relatively greater in small than

in large shops, and, third, that it is greater for fine and light than for coarse and heavy work. These conflicting conditions entering into general averages in various unassignable proportions deprive such averages of the most definite significance.

The examples furnished by individual shops in which the conditions are quite definitely known will be found of more value, and some such examples will hereafter be cited under the reference to division of labor in shops. The foregoing statements of percentages of skilled labor are of some value relatively, but owing to the fact that such percentages to be true must be calculated from the minimum average of number of workmen, allowing for all lost time, and the usual average stated being probably 15 or 20 per cent. above this minimum, the calculated percentage of skilled labor is very much less than it should be. For the whole country the calculated percentage is estimated to average about half of the actual proportion of skilled labor, which should range from 60 to 80 per cent. of all instead of, as calculated, from 30 to 40 per cent.

DIVISION OF LABOR.—The division of labor in shops may best be illustrated by examples in which some data of the character of the work are given.

A large shop in the west, employing several hundred operatives, has the following division of labor, rated in percentages of the whole number of hands:

	Per cent.
Vise hands	0.080
Other machinists	0.335
Molders and core-makers	0.127
Laborers in foundery	0.075
Other common labor	0.125
Boiler-makers	0.090
Blacksmiths	0.056
Wood-workers	0.052
Office work, time-keeping, etc	0.060
	1.000

About 63 per cent. of the labor in the foundery is skilled. Some milling, woodworking, and other machinery is included in the product of the shop. Boiler-making was a minor portion of the work, perhaps one-fifth or one sixth, counting all the labor involved. During the year the average attendance of men was 70 per cent. of the maximum. The shop was running upon the average only 70 per cent. of full time.

In the above showing, the skilled and high-priced labor constitutes a large percentage of the whole number of hands, viz., nearly 80 per cent. The variety of work done is great. Estimating by the rule previously cited, with allowance for lost time, we find average wages paid per day, \$2 04, stated average wages for skilled men being \$2 25, and for unskilled, \$1 35, whence we have a showing of 76 per cent. of skilled men, which accords perfectly with the results of the more detailed inquiry. The importance of full time and steady work, and the disturbance which a slight variation in the accuracy of statement of average number of operatives may cause in the calculation of average wages is set forth in the following table from the undoubtedly reliable returns of this establishment:

Rates per annum per operative.

Number of operatives.	Capital.	Wages.	Materials.	Products.
Maximum	\$1,200	\$300	\$460	\$1,200
Average	1,715	428	657	1,715
Average at full time	2,449	612	923	2,449

The proportionate value of products to materials for the shop in question indicates that its chief work is the manufacture of a fine class of engines and machinery. If we assign the common labor and clerical labor in suitable proportions to the various distinct departments, we obtain in round numbers the following exhibit of the allotment of labor:

	Per cent.
Machinery, fitting and assembling	50
Foundery work	21
Boiler-work	16
Blacksmithing	7
Wood-working	6

It is of interest to compare with the foregoing the division of labor in another large shop in which the element of boiler-making is excluded, while the engine work is of a heavier character, some milling and other machinery being included in the product:

	Per cent.
Machinists	35
Molders	10
Core-makers	4
Laborers in foundery	17½
Other common labor	9
Blacksmiths	4
Wood-workers	10
Pattern-makers	2½
Office, watchmen, and teaming	8
	100

The proportion of wood-workers is large, because the manufacture of mill machinery with wood framing is included, but the most notable feature is in the increased proportion of laborers in the foundery, while the proportion of molders and core-makers is scarcely increased. This is simply because the work deals with heavier castings. Blacksmithing also is required upon fewer and heavier pieces. In the foundery only 44 per cent. of the labor is skilled. Full time is reported, but the average is only 84 per cent. as great as the maximum force employed. The skilled and high-priced labor appears less than 74 per cent. of all. Applying the rule for calculating this percentage from the average number of men, and the wages paid, we have: Average wages paid per day, \$1 80; stated average wages being for skilled men, \$2, and for unskilled, \$1 25, whence we have a showing of 73 per cent. of skilled men, which accords with the detailed results. The rates per annum per operative are for the actual average number of operatives: Capital, \$887; wages, \$539; materials, \$929; products, \$1,685, the relative values of products and materials indicating heavier work than in the preceding case. A somewhat smaller shop in the same locality, and engaged in the manufacture of a cheaper grade of engines, has the following statistics: Full time is reported, and the average number of operatives is 96 per cent. of the maximum; per annum per operative, capital amounts to \$1,000; wages, \$600; materials, \$1,080; products, \$2,200. The calculated proportion of skilled labor is 60 per cent., the average wages being \$2; wages for skilled men, \$2 50; unskilled, \$1 25. The work embraces less variety than the other, and being more stereotyped, a smaller percentage of skilled labor is required.

The following statistics are given of five large shops in the east, all making automatic engines of large size. All report full time and a daily period of ten hours' work throughout the year:

	1.	2.	3.	4.	5.
Percentage of average to maximum number of operatives	79	81	100	100	90
Per annum per operative:					
Capital	\$1,205 00	\$477 00	\$3,253 00	\$1,000 00	\$166 00 (?)
Wages	687 00	415 00	532 00	500 00	317 00
Material	439 00	1,197 00	1,833 00	500 00	417 00
Product	1,205 00	1,833 00	1,482 00	1,200 00	833 00
Average wages:					
Skilled labor	2 75	2 12	2 50	2 50	2 00
Unskilled labor	1 50	1 25	1 35	1 25	1 25
Apparent average wages paid	2 29	1 38	1 77	1 66	1 05
Apparent per cent. skilled labor	63	15	37	67	(a)

a No result.

By reason of overstatement of the average numbers of operatives the calculated average wages paid appear too low in 2, 3, and 5. The apparent percentages of skilled labor are too low in 2 and 3, and for 5 the result is absurd on the same account. Correction would of course alter the financial showing per operative. Shop 1 is devoted to very heavy contract work. Shop 2 makes smaller engines to stereotyped patterns, and turns out a much greater product per operative. If in shop 2 the time or number of operatives had been 20 per cent. overestimated, we would have: Capital, \$572; wages, \$495; material, \$1,436; product, \$2,200 per operative; apparent average wages, \$1 65; skilled labor, 46 per cent. of all. Twenty-three per cent. overestimate would give 52 per cent. skilled labor, and so on. The shop in question is well known; its work is of a fine character; its departments are similar to those of shops already cited, and the proportion of skilled labor is necessarily large, probably as much as 60 per cent. of all. The return of skilled wages also shows a low rate. In only four state averages is it lower, and for the section in which the shop is located it is very low. The error in this and in similar cases is easy to place. It is due simply to overstatement of average number of operatives on a basis of full time. It is not that such returns are not rendered in good faith. The usual attendance of hands is stated when the shop is running at its normal capacity. The full usual time is stated. Stoppage and half-time are stated in units of months. But if we take the time-keeper's book we find here and there a few days' or weeks' shut down of a part of the works, or the normal capacity has not been as well maintained as is supposed, and the actual percentage of time to be deducted on this account may be surprisingly large. The practice of closing an hour earlier on Saturday makes $1\frac{2}{3}$ per cent. difference. Two weeks' shut down makes 4 per cent. difference, and an hour a day short for half the year, 5 per cent. That the mean yearly average is overstated in the aggregate is plainly indicated by three things: First, inconsistency in the calculated proportion of skilled labor, as shown by many special inquiries; second, the value of the product per operative, *which has been calculated for every shop*, and often appears too low; third, the number of large shops in which (as in 3 and 4) the average number of operatives is returned as equal to the maximum. The return is so made by about one-third of all the shops.

I will cite the statistics of three more engine-building shops, which present fair examples; 6, of a large shop building automatic engines; 7, of a shop building marine engines exclusively, and, 8, of a smaller shop, this last being on the Pacific coast.

	6.	7.	8.
Percentage of average to maximum number of operatives	100	100	100
Per annum per operative:			
Capital	$1,317 00	$500 00	$625 00
Wages	452 00	480 00	792 00
Material	643 00	400 00	250 00
Product	1,327 00	900 00	1,375 00
Average wages:			
Skilled labor	1 90	2 00	3 50
Unskilled labor	1 15	1 25	2 00
Apparent average wages paid	1 50	1 60	2 64
Apparent per cent. skilled labor	53	53	57

All return full time and ten hours a day throughout the year.

Of the division of labor in three of the largest shops in the country in which the manufacture of boilers and engines is combined under one management, the following tabulation is made:

	a.	*b.*	*c.*
	Per cent.	*Per cent.*	*Per cent.*
Machine-shop	36	34	37
Foundery	30	23	21
Boiler work	16	23	25
Blacksmithing	7	9	10
Office work, etc	7	7	5
Pattern-making	4	4	2

The proportion of skilled labor in the foundery ranges from one-half to three-fourths. The shops are located in the south and west. All employ the most improved tools and facilities, and do thoroughly good work, and all make a specialty of portable engines, building also stationary engines and boilers. Their statistics, as returned, are given as follows, and with them, under the head *d*, the statistics of a smaller shop in New England, in which the division of labor is similar, but with a greater proportion of boiler work:

	a.	*b.*	*c.*	*d.*
Percentage of average to maximum number of operatives	100	100	91	100
Per annum per operative:				
Capital	$777 00	$350 00	$625 00	$961 00
Wages	444 00	350 00	312 00	654 00
Material	555 00	402 00	781 00	2,212 00
Product	1,222 00	900 00	1,250 00	3,173 00
Average wages:				
Skilled labor	1 75	2 00	1 75	2 75
Unskilled labor	1 00	1 00	1 00	1 50
Apparent average wages paid	1 48	1 17	1 04	2 18
Apparent per cent. skilled labor	64	17	5	54

The actual percentage of skilled labor is probably not less than 60 per cent. in these cases. All return full time, and ten hours is the customary time of day's labor, but for half the year *a* runs at eight hours and *d* at nine hours a day, for which allowance is made.

Not so much is to be said in regard to the division of labor in shops devoted to the exclusive manufacture of boilers. In this we may usually estimate about 50 per cent. for the skilled boiler-making crafts, 20 per cent. for laborers and helpers in boiler-making, 20 per cent. foundery work for the castings involved, and 10 per cent. for the blacksmiting and other work. Sometimes the shop work is confined to the working of sheet-steel and iron, foundery work not being included. In the strict work of boiler-making we may for heavy work estimate riveting and calking to require 54 per cent. of the labor; flange-turning, and the most skilled work of boiler-making, 18 per cent.; common labor, rivet heating, and helping, 28 per cent. There are usually about half as many rivet-heaters as riveters. The rivet-heaters are not infrequently boys, the work being both light and unskilled.

Of the statistics of boiler-shops, the following six examples may be taken as exhibiting the character of the returns. The real proportion of skilled labor may be taken at between 50 and 70 per cent., possibly less than 50 in tank work, and a correction of the actual returns, as here given, may be based on this understanding. The shop *a* makes marine boilers, and is located on the Pacific coast; *b*, located in New England, makes large stationary

boilers of a uniform type; *c*, located in the west, makes river-boat boilers mainly, and *d*, also in the west, is a large shop, making stationary and portable boilers. A shop making tanks and boilers, mostly a low grade of work, is represented by *e*, and a small shop in the south, devoted to boiler-making and repairs, by *f*:

	a.	*b.*	*c.*	*d.*	*e.*	*f.*
Percentage of average to maximum number of operatives	53	100	46	89	100	100
Per annum per operative:						
Capital	$526 00	$1, 200 00	$750 00	$2, 727 00	$952 00	$421 00
Wages	789 00	600 00	932 00	655 00	261 00	333 00
Material	1, 052 00	2, 000 00	2, 315 00	1, 704 00	936 00	526 00
Product	2, 000 00	3, 200 00	3, 592 00	2, 500 00	1, 248 00	1, 579 00
Average wages:						
Skilled labor	3 50	2 75	2 50	2 50	2 25	2 50
Unskilled labor	2 00	1 50	1 75	1 50	85	1 00
Apparent average wages paid	2 97	2 00	3 11	2 18	87	1 11
Apparent percentage skilled labor	65	40	(*a*)	68	02	07
Time returned	Full.	Full.	¾ to full.	Full.	Full.	⅚ to full.
Average time, daily labor	9½	10	10	10	10	9½

a No result.

The showings of *e* and *f* are due to the usual element of overstated average time. The peculiar showing of *c* is due to unspecified overwork paid at extra wages. This of course swells the value of the product.

Rates of wages.—As there are usually several grades of wages paid for skilled labor, the amount stated as the wages of skilled labor is an average given by the manufacturer, and obtained from several rates. In engine-building, ordinary labor was not usually paid at less than $1 per day at the time of taking the Census, exceptions being mainly the labor of children or youth or other labor less than that of full hands, especially in small shops remote from manufacturing centers. In the south we find colored laborers employed in the founderies and blacksmith shops, not in the skilled crafts, but only as helpers and blacksmith's strikers.

The highest average wages are paid in the small, isolated repair shops, but in these the work is less uniform than in the large shops, while in their localities the purchasing capacity of money is often smaller for the same amount than near the large manufacturing centers.

Since 1870 rates of wages appear upon the average to have fallen off about 12 per cent., but it should be remembered that although the intrinsic worth of the product is now probably greater per operative than in 1870, its commercial value has fallen off about 15 per cent. while rated per operative the difference between the value of product and the cost of materials and labor—a difference which may be taken to include running expenses, avails, and interest on capital investment, has fallen off about 30 per cent. Quality considered, the same amount of money would have purchased perhaps 20 to 25 per cent. more steam machinery in 1880 than in 1870, although the violent fluctuations in the cost of iron during 1880 were enough to impair the accuracy of any general statement. There can, however, be no doubt but that the general purchasing power of wages paid in 1880 was greater than in 1870.

There is one evidence of the state of manufacture in the various sections which deserves to be noted here. It is in the relative rating of skilled and unskilled labor. Positively, the rates may furnish but an uncertain gauge of the skill or of the comforts of the workman, since $3 50 a day, with irregular time of work in one section, may yield a smaller living return than $2 50 a day with steady work and low cost of living in another section. But when we note the relative rates for skilled and unskilled labor we see at once that in those sections in which mechanical facilities are most fully developed and manufacture is pursued upon the largest scale, the wages of skilled mechanics are sometimes no more than once and two-thirds the wages of unskilled workmen, while in small shops with few facilities and little organization, the rates for skilled men are sometimes two, three, four, or even five times as much as for the unskilled. In the former cases the unskilled labor is of a higher class than in the latter.

The manufacture of machinery differs from the manufacture of iron in its cruder forms, and to some extent also from boiler-making, in the influence which it exerts upon the condition of the laborer. In the latter, as in some other classes of manufacture, improved and enlarged plants tend mainly to increase the number of laborers of little skill. The machine often takes the place of skill in a considerable body of workers. But the manufacture of steam engines and other machinery is so various in its processes and so complex in its organism that its improvements will be found to stimulate intelligence.

For the several sections we find that in numerical value the wages of the skilled men are slightly more uniform than the wages of the unskilled, but in intrinsic worth—that is, in local purchasing power—the wages of the skilled men are the more uniform than those of the unskilled. The range of wages of skilled men is from $4 50 to $1 90 ($3 to $2 25 usual). For unskilled men the range of wages is from $2 35 to 50 cents ($1 40 to $1 usual). Taking the averages of the shops of large sections, the ratio of skilled to unskilled wages is about 1.70 to 1 for New England,

1.75 to 1 for the west and northwest, about 2 to 1 for the middle, and about 2.15 to 1 for the southern states. This average is taken by states, and the influence of small shops is offset against that of large, making the ratio too great. Thus, for the southern states, if the average ratio were taken proportionately to the numbers of operatives in the shops, the influence of the large shops in Maryland and Virginia would bring the average ratio below 2. But the lowest ratios occur in the large manufacturing centers, where skilled labor is most demanded and best appreciated. In these places the intrinsic worth of the wages of skilled men is relatively high, and as the value of the wages of unskilled men approaches nearest to that of skilled men in these same localities, there is greater variation in the true purchasing value of the wages of unskilled men in the various sections than would appear from the numerical rates of wages.

In engine building, as in some kindred industries, the higher development of the work by more productive methods elevates alike the intelligence required and the pay and living condition of the common laborer. Nor should it be forgotten that common labor, unlike skilled craft, is interchangeable among all industries in any given section of the country. Such tendencies then are to elevate common labor, not in special or protected industries, but as a whole, and it is unquestionably so elevated in this country. Thus, while the manufacture of agricultural machinery has released great populations from the necessity of tilling the soil, the wages of the farm laborer are increased by the drawing of labor into manufactures. The increased efficiency and the increased returns are shared by nearly every class of labor so long as the country is, as at present, in a growing state.

I conclude this consideration by giving the following averages for large numbers of shops making, respectively, engines and boilers, engines and machinery, and boilers exclusively. The average number of operatives is reduced to a uniform scale of ten hours' a day labor, and full time during the year so far as the lost time is returned, but it is still considered that there is an average of between 10 and 20 per cent. of lost time, for which no allowance is made, or, in other words, the nominal number of hours' labor being ten hours a day, a strict allowance for all lost time would probably reduce the average to something less than nine hours a day, a fact to be borne in mind when comparing rates of wages with those of foreign shops in which the men have to work a greater number of hours a day.

Of the shops engaged in this manufacture in the United States, only five report twelve hours' a day labor, and in these this rate is maintained only half the year. It may then be said that the averages for wages of skilled and unskilled labor are based upon ten hours' a day labor, but I have based the average daily wages paid at the rate of eight and one-half hours' labor for the stated average number of operatives. This may seem a large reduction, but even this is not large enough to account for the proper proportion of skilled labor in the large boiler-shops.

BOILER-MAKING.—Nine large shops, with 1,517 operatives, show an average rate of wages for skilled labor of \$2 52; for unskilled, \$1 24; ratio of wages of skilled to wages of unskilled labor, 2.03. Average wages paid at ten hours, \$1 53; eight and one-half hours, \$1 30; percentage of skilled labor, 22 per cent. (underestimated). Ninety-seven smaller shops, with 2,006 operatives, show an average rate of wages for skilled labor of \$2 36; for unskilled, \$1 35. Average wages paid at ten hours, \$1 94; at eight and one-half hours, \$1 65; ratio of wages of skilled to wages of unskilled labor, 1.75. Proportion of skilled labor, 58 per cent.

BOILERS AND ENGINES.—Seventeen large shops, with 3,070 operatives, show average wages: skilled labor, \$2 21; unskilled, \$1 27; ratio, 1.74. Average wages paid at ten hours, \$1 78; at eight and one-half hours, \$1 51. Proportion of skilled labor, 54 per cent.

Eighty smaller shops, with 1,885 operatives, show average wages: skilled labor, \$2 40; unskilled, \$1 30; ratio, 1.85. Average wages paid at ten hours, \$1 93; at eight and one-half hours, \$1 64. Proportion of skilled labor, 57 per cent.

ENGINES AND MACHINERY.—Fourteen large shops, with 3,213 operatives, show average wages: skilled labor, \$2 21; unskilled, \$1 27; ratio, 1.74; by a coincidence, the same as in the manufacture of boilers and engines in the large shops cited. Average wages paid at ten hours, \$1 98; at eight and one-half hours, \$1 69. Proportion of skilled labor, 75 per cent.

Eighty-three smaller shops, with 2,313 operatives, show average wages: skilled, \$2 32; unskilled, \$1 25; ratio, 1.85. Average wages paid at ten hours, \$1 87; at eight and one-half hours, \$1 59. Proportion of skilled labor, 58 per cent.

The arbitrary time allowance taken causes the proportion of skilled labor to appear smaller than probable in most of the foregoing cases. The object in taking averages of selected cases is, so far as possible, to exclude anomalous conditions and to express general and ordinary conditions, for the manufacture of engines and boilers is associated with many other manufactures, from bridge iron to hardware and agricultural woodwork. There is a growing tendency to build machinery with a steam cylinder to each machine. By this arrangement power is advantageously applied, and does not run to waste in transmission, nor when the machine is at rest. Of this, stone-crushers, calendering-machines, nail- and freightage-machines, hammers, drops, trips, windlasses, and many kinds of special machinery, may be cited as examples, and these will suffice to indicate how impossible it is to make a clearly defined separation between engine-building and other machine work.

THE MANUFACTURE OF LARGE AND SMALL ENGINES AND ENGINE PARTS.

The following observations upon the manufacture of steam-engines are not founded upon the practice of any particular builder or manufacturer, but upon a mass of data often more or less contradictory and derived from many sources. There is in the manufacture a great variation in the product and a considerable variation in the methods pursued, so that there must be many exceptions to any general statement. In bids for specified machinery in competition, prices will often range very widely, sometimes as 1 to 2, or more, and general statements of so varied a manufacture as steam-engine building are, it must be confessed, a somewhat vague specification.

In many shops there is a highly developed system, and if in some of them the productive operations are more or less merged or confused, some knowledge and principles of value may yet be derived from their study.

The steam-engine is made up of metal parts of great variety in shape and finish. The great weight of the parts is of cast-iron, but some important parts of simpler forms are forged. In casting, the element of cost which is most noticeable is the size of the piece, small castings costing more by the pound than large. It has been suggested that a formula might be utilized in which weight of castings and number of pieces should so enter that the proper charge for any specified work of casting might be thereby deduced, and it may even be said that the methods of estimate sometimes employed by founderymen are tantamount to the use of some such formula. Peculiarity of form requiring extra care in moulding is also an element which much be considered in estimating the cost of castings. The next element of cost is in the machine-tooling, which differs with the surface machined and with the accuracy of work, the facing of a slide-valve, for example, costing far more for the area surfaced than such work as the planing of the frame feet on which the engine rests. In ordinary practice the machining of small pieces for similar areas surfaced costs vastly more than the machining of large pieces, on account of the time lost in resetting the work, which in many classes of shop-work is two, three, or more times the period during which the tool operates upon the work. For example, to bore out in 3- by 4-inch cylinders the same surface as would exist in a 90- by 144-inch cylinder would require the small work to be reset and centered over a thousand times. The cost of assembling is not closely assignable, and the cost of investment, teaming, common and clerical labor, etc., can only be estimated in a lump percentage. In these last items chiefly reside the opportunities for profit due to careful management and effective business system.

Let us now mentally place before us an engine of an ordinary style and size, a horizontal slide-valve engine, with a 10- by 20-inch cylinder, an engine commonly rated at 30 horse-power nominal, and which will realize that power with fair economy under proper conditions of speed and pressure. Such an engine has a cylinder-volume of 0.91 cubic feet; it will weigh without auxiliary irons and fitting between 5,000 and 7,000 pounds, and will cost between $600 and $800.

Its parts are very numerous if we enumerate every pin, bolt, and washer, but those which constitute the principal elements of weight and cost may be easily considered. I divide them for convenience of consideration into three classes, heavy, medium, and light. In the first I place the fly-wheel, the frame, and the disc-crank and main shaft together, the engine considered having a disc-crank which, like the fly-wheel, assists in the regulation of the speed. The cylinder (shell), which weighs about 325 pounds, might be placed in this class, but as the considerable proportion of tooling upon it brings it more into keeping with the next class, it is placed there, and with it the steam-chest, slide-bracket, cylinder-heads, piston, outboard bearing-block, main bearing-cap and quarter-boxes, connecting-rod, throttle-valve, and large bolts. The cylinder shell usually weighs more in proportion to the weight of the engine in the small than in the large engines, but some other pieces classed with it increase in weight more rapidly than the average of the engine parts as we pass from the smaller to the larger sizes of the engine. As comparatively light parts are classed the numerous components of the governor, the valve-glands and slide-guides, piston-rod, eccentric, strap, bolts and pin, oil-cups, packing-rings, shoes, springs, crank and cross-head boxes, liners, straps and keys, main and valve cross-heads, slide-valve, governor-pulley, eccentric-rod, and piston-glands and bolts.

The parts classed as "heavy" are estimated to weigh about 4,600 pounds; as medium, about 640 pounds (about half of which is in the cylinder); as light, about 140 pounds, making their relative weight about 85½, 12, and 2½ per cent. of the total weight respectively. But in the estimate of the values of these parts, with an added percentage for general and contingent expenses, we may consider that the heavy parts represent 56 per cent., the medium parts 24 per cent., and the light parts 20 per cent. of the value of the engine.

For the same surface machined the work upon the fly-wheel costs less than upon any other part, because the cut is a long continuous one, and balance-wheels and pulleys are such staple articles that labor may be employed to the best advantage upon them, and without the diversion of changing the kind of work, which is always fatal to a high efficiency. Precisely the reverse is true of the small engine parts, which, not being required in large numbers, are often made at a disadvantage in respect to economy.

The cost of material and casting ranges from about 2½ cents for the large to 3½ cents for small iron castings. Cored work commonly commands a higher rate than castings made without cores, and contracts are often let at an average price for all castings, large and small. Wrought-iron parts and large parts of machine steel (such as

shafts) cost 2½ to 3 cents a pound, but forged crank-shafts with return-cranks have a higher cost, which increases with the size, as does the difficulty of forging. Parts of brass or bronze cost usually from 20 to 30 cents, of malleable iron from 6 to 12 cents, and of cast-steel from 10 to 15 cents a pound, unfinished.

The difference in cost of completed parts by the pound is chiefly in the labor of machining and finishing. The greatest improvement in economy is to be sought here, and wherever iron or steel of manufactured shapes can be utilized, the increased cost of material may be much more than compensated by the decreased cost of work in the shop. The stock for a wrought-iron connecting-rod may weigh 50 pounds and require $10 worth of labor in turning and finishing. A cast-steel rod to take its place may cost four times as much by the pound, but its weight is about half that of the wrought-iron stock, while the cost of machine work is reduced to $5, showing a decided advantage in the use of the costlier material.

Of the cost of work on parts of engines, the figures cited are calculated to convey fair average ideas, and at some time to serve as a significant gauge of future progress. From them there is considerable variation, and one is often surprised in going over actual cases to find how much certain machine-work costs when inefficient methods are employed, and how insignificant the cost becomes when improved machinery is applied. I do not here consider the cost of investment in machinery. An engine part which costs $4 forged at the anvil and finished without special tools, costs only 1½ cents when drop-forged between steel dies and finished by special milling-tools.

For the 10 by 20 engine the pound-costs for machining will be about ½ cent for the fly-wheel, ¾ cent for the frame, 2 cents for the shaft and disc-crank, 2 cents for the cylinder, 8 cents for the eccentric-rod and strap, 10 cents for the piston-rod, 10 cents for the slide-valve, and 20 cents for the connecting-rod. The parts specified as heavy will cost about 2½ cents for material, 1 cent for work; medium, 3½ cents for material, 5 cents for work; light, 4½ cents for material, 30 cents or more for work.

As we pass from the small to the large sizes of engines it is obvious that we will soon reach a point at which the large parts of a small engine would be no heavier than the small parts of a large one, and thus the character of the manufacture changes. For an engine 6 inches diameter of cylinder by 12 inches stroke of piston, called an 8 horse-power engine, the percentages of total weight are about 78, 18, and 4 per cent. for the specified heavy, medium, and light components. For a 20- by 30-inch engine, called 100 horse-power, these percentages may be rated at 90, 8½, and 1½ per cent., respectively. The percentages of total cost were found to be 51, 28, and 21 for the small, against 75, 14, and 11 per cent. for the large engine respectively. The cases were not strictly comparable in regard to some conditions, but the subject can only be treated by approximations.

The variation in the increase of weight of the different components as we proceed from the small to the large sizes of an engine bears upon the question of economy of material, and warrants variations in design for different sizes.

Let us institute a few comparisons on this score, taking a 6- by 12-inch, a 10- by 20-inch, and a 24- by 36-inch engine for purposes of contrast.

Weights of engines.

	6- by 12-inch.	10- by 20-inch.	24- by 36-inch.
	Pounds.	*Pounds.*	*Pounds.*
Weight of engine with fly	1,600	5,700	35,000
Weight of cylinder-shell	107	326	1,676
Weight of main shaft	8	38	314
Weight, in cast-iron, of a solid cylinder equal to the cylinder space	88	408	4,235

Putting the same comparatively, the weights for the small engine being taken as units:

	6- by 12-inch.	10- by 20-inch.	24- by 36-inch.
Engine	1	3.56	23.75
Cylinder-shell	1	3.05	15.66
Main shaft	1	4.75	39.25
Solid cylinder	1	4.64	48.12

It is obvious that a disc-crank suitable for small sizes of engine would add disproportionately to the weight of a long-stroke engine. In parts like the cylinder-shell, whose dimensions are calculated with the addition of a constant quantity to secure sufficient margin for stiffness, the increment provided for rigidity becomes relatively less and less as the cylinders increase in size. In cross-heads and other small parts there is also a surplus of metal in the small as compared with the large sizes. The area in cross-section of bolts for the cylinder-heads varies under similar proportions and pressures about as the weight of the shell, but the cylinder-heads weigh proportionately more in the larger sizes. In the above examples we see that the weight of the main shaft, which is one-thirteenth

of that of the cylinder-shell in the 6- by 12-inch engine, has increased to nearly one-fifth of it in the 24- by 36-inch engine, and in larger sizes its weight is relatively much greater. The piston-head is relatively heavier in the larger engines, but the piston-rods and connecting-rods are relatively lighter.

Considering the weight of a cylinder volume as the unit of comparison, the frame and nearly every part of the engine is relatively lighter in the larger sizes, but considering, as understood in the foregoing remarks, the average weight of the engine parts as the basis of comparison, then we have on one side the frame, main shaft, crank, cylinder-heads, piston-head, and usually the fly-wheel, growing relatively heavier, and the cylinder shell and most of the small parts growing relatively lighter as we proceed from the smaller to the larger sizes of engine. The ordinary weight of fly-wheel for the specified engines running at 400 feet of piston speed per minute is as follows, actually and relatively:

	6- by 12-inch.	10- by 20-inch.	24- by 36-inch.
	Pounds.	*Pounds.*	*Pounds.*
Weight of fly	500	2,040	12,000
Relatively	1	4.08	24.00

The necessary weight is of course dependent upon the rotative speed, and is relatively less in short-stroke engines.

As we pass from the manufacture of small to that of large engines, the machine-tooling and workmanship is a continually diminishing element of cost, and the cost of material becomes more and more the chief element. The small parts, upon which much work is done, become relatively lighter and less important, and the work upon the large parts is more continuous, while similar areas of surface are more cheaply machined. We notice this even in the aspect of the shops. Where large engines are built the tools are of course larger and heavier, and the shop space per man is greater. It also appears in the statistics determining the relative costs of labor and material. But while the statistics may enable us to make a shrewd guess as to the character of the work, they are not a certain guide in these respects. The cost of labor is relatively great in work of repairs, as well as in building small engines, while the cost of material returned may be relatively great in the manufacture of small engines by parties who purchase some of the engine parts in a more or less finished state.

COST OF AN ENGINE FRAME.—The following analysis of the elements of cost by the pound of an engine frame finished, weighing about a ton, and worth $210, may be of interest, although it might go without saying that these elements would be more or less varied under different conditions of manufacture. It shows in a very graphic way how the cost of machinery is distributed, about how much goes toward paying for the use of valuable tools, and how much for the use of buildings, supervision, and facilities for obtaining credit, and for marketing and transporting the product. It shows how much goes for the labor of mining and transporting the constituent materials, and how much for such auxiliary materials as files, oil, tools, power, and foundery coal, flux, sand, water, gas, and other contingent expenses, and it shows finally how much goes for labor in the foundery, and for the various kinds of machine-work. It is, to be sure, only an estimate for a single engine part, more or less variable in every condition of cost, and yet the figures are not so far removed from ordinary conditions as to be misleading. The interest on investment and machine plant is divided pro rata by a division of the capital investment among the annual products of that investment:

	Amount.	Amount per pound.
		Cents.
Interest on machine plant	$8 00	0⅖
Interest on other investment	32 00	1⅗
Middlemen's profit in selling	25 00	1¼
Constituent material	35 00	1¾
Auxiliary material and expenses	48 00	2⅖
Foundery labor, 200 hours	40 00	2
Machine-shop labor (*a*)	22 00	1 1/10
Total	210 00	10½

a Twenty hours fitting and setting up; 15 hours planing; 10 hours filing; 5 hours drilling; 5 hours boring; 5 hours supervision; 15 hours other labor.

It is also to be noted that the value of frame is taken as it exists in the finished engine with its proportionate allowance of cost for assembling and marketing.

RELATIVE COST OF PORTABLE ENGINE PARTS.—In passing from a 6- by 12-inch to a 10- by 20-inch mounted portable engine, we find that the weight is trebled and the cylinder capacity is increased fivefold, while the price is nearly doubled.

While the average cost of parts is nearly doubled, it will be noted that the price of some parts is increased more than twice, while there is little or no change in the price of other parts. This conveys an idea of the relative increase in the cost of manufacture of the several parts.

Taking the prices of the several parts of the 6- by 12-inch engine as units, and comparing with them the prices of similar parts of the 10- by 20-inch engine, we find for the following specified parts the following ratios of cost:

The ratio is 1, or value the same for both sizes, for brake-shaft box, brake-shoes, cylinder-cock, and angle-valve for blower.

The ratio falls between 1 and 1.25 for air-cock, axle-pivot, axle-pivot ring, brake-lever ratchet, connecting-rod liner, crank-strap, and double trees.

The ratio falls between 1.25 and 1.5 for axle-saddle, brake, brake-ratchet, brake-shaft, box-cap, rock-shaft, and double-seat valve.

The ratio falls between 1.5 and 2 for cylinder-head (front), cylinder, cross-head key, cross-head bracket, connecting-rod body, connecting-rod crank-box, brake-lever, brake-reach rod, ash-door, and axle-cap. The relative price of boring cylinder is 1.8 to 1 in the two sizes.

The ratio falls between 2 and 3 for axle front, ash-door housing, rear axle, bracket legs for skid engine, cap for shaft-bearing, check-valves, crank and crank-pin, cross-head, cylinder-head (back), cylinder-head guide-cap, and eccentric.

The ratio is above 3 for band-wheel and cylinder lagging.

These figures generally bear out our conclusion from the study of stationary engine manufacture, namely, that as the size of engine increases the weight element of cost increases more rapidly than the work (machining) element of cost. Improved economy is to be sought chiefly in a system of manufacturing component parts in quantities.

To any one familiar with this class of machinery the names above specified will convey a sufficiently clear idea of the shape and character of the prices.

FOUNDERY WORK.—The foundery of a large engine-works presents a very different appearance from that of a sewing-machine shop, although it may be remarked that in some cases the foundery absorbs similar relative proportions of the whole amount of labor employed in the respective establishments, and also that the average weight of metal cast per operative employed in the foundery may not differ greatly in the two cases. The small-parts foundery has an orderly appearance, with rows of small flasks arranged in symmetry, but the foundery devoted to heavy work presents as much a scene of confusion as a systematic process of manufacture can well exhibit.

In most engine-works loam and green sand molding are carried on in the same foundery. The cupolas are commonly placed on one side of the foundery, near the loam-molding end, and conveniently at hand are one or more heavy cranes, with a sweep enabling them to carry the molds formed upon the foundery floor to large drying ovens at the nearer side and end of the foundery. Sometimes overhead and traversing railways are used, but the ordinary dependence is upon large jib cranes, which, for the heaviest work, are operated by steam engines. The floor of this part of the foundery is not only diversified by piles of brick and sand, but is thickly set with temporary molds and furnaces of brick and clay, with flues extending from point to point of the uneven surface, and temporary brackets and sweep fixtures above them. The molding with flasks is done in the farther end of the foundery, and if there be shed or yard room in the vicinity, it will probably be found littered with an accumulation of disused flasks of various shapes and descriptions. In a small building near this end of the foundery, or in a loft above it, we will commonly find the pattern-store-room, with a stock of models of machine parts, prepared at great expense, and only a few of which can be employed at any one time. The rumblers, or tumbling barrels, for cleaning small castings, are usually set apart from the foundery in a partitioned inclosure, and the blower is placed on a platform among the foundery rafters, its draft-pipes extending to the several cupolas. The cupolas having their vents above the foundery floor are charged from above, outside the foundery. An incline leads to this part of the cupola, and up this incline the iron, flux, and fuel are wheeled or otherwise carried. Some of the larger founderies have hoists for this purpose and others have inclined railways operated by power. The sheds, with bins for the storage of coal, sand, fire-clay, and other supplies, are also necessary adjuncts of the foundery.

In a large engine- and boiler-works, the foundery floor usually constitutes between one-sixth and one-eighth of the total floor-space, and the number of square feet of floor-space per operative usually ranges between 64 and 100 square feet. In American shops the ordinary foundery for gray iron castings is a very conspicuous feature. In engine-building, a distinctive difference between American and English practice lies in the greater use of cast iron in America. This may be largely attributed to the excellence of American cast iron as compared with the English in the grades used for engine castings, the English Cleveland ore being liable to produce porous castings. Eccentric straps, brackets, and portions of the framing, made of wrought iron in England, are almost invariably made of cast iron here. In English steamers the bed-plates and condensers of the engines are frequently made of wrought-iron, but here the frames and the condensers (unless cylindrical) are made of cast iron. Of course there are some exceptions. The United States steamer Susquehanna was built in 1847 with wrought-iron engine frames, but the ordinary rule is cast iron. The tendency is to avoid blacksmithing, and if cast iron be unsuitable for an engine part, cast-steel or malleable iron, both of which are in growing favor, are often used in preference to wrought-iron forgings, especially if the piece be of a complex pattern. The forged parts of a frame are usually built up and bolted together, where a similar frame of cast iron would be made in one piece. In some cases the cylinders,

frames, and bed-plates of small upright engines are cast in one piece, where they were formerly cast in three. All the coring, boring, reaming, counter-sinking, planing and turning for at least eight large bolts are thus dispensed with, and the construction is lighter and more steady.

In the handling and transformation of materials in the foundery, the proportions and economy of these materials, and the waste of metal in founding, first merit our consideration. The engine-foundery employs pig-iron as its raw material; but to go back a step, in casting iron pigs the ore weighs $1\frac{1}{2}$ to 3 times as much as the pig-iron produced, the limestone (flux) used ranging from one-twelfth to five-fourths of the weight of the pig, and the fuel from three-fourths to nine-fourths, usually about five-fourths of the weight of the pig. In casting iron pigs the reduction of weight from the ore to the pigs ranges from 20 to 75 per cent., and the further reduction of weight from the pigs to the formed casting may be amply estimated at 8 or 10 per cent. The wastage is greater than this for scrap and burnt iron. The loss of weight in melting is stated for new iron (pigs) to be 2 to 8 per cent. in stove founderies, and 4 to 10 per cent. in machinery and engine founderies, but for old plate- and sheet-iron the loss is from 20 to 30 per cent., and for burnt iron from 25 to as high as 60 per cent.

In the final casting of the machine parts the proportion of coal to iron is different and very much less than in casting pigs, the proportions being, coal 1 to iron from 7 to 9 in ordinary cases and depending upon the fluidity required in the iron.

In founding small machine parts the early part of the day and until about 3 o'clock in the afternoon is occupied in molding, and afterward the men take up the work of pouring the metal into the molds.

The power employed in a foundery is mainly used for blowing and rumbling. It averages in ordinary cases about four-fifths of a horse-power per operative (molders, core-makers, and laborers) in the foundery. As a rule the larger the capacity of the cupolas, the smaller is the relative amount of power required for the same metal flowed.

The output of a foundery by weight per operative varies greatly with the character of the work. It is in most cases fully as great for small green-sand castings as for heavy loam-castings, because the latter require so much more work of preparation and so many more laborers and helpers that the average daily flow per operative appears reduced. In a large foundery, with 96 operatives, having two 5-foot cupolas, 10,000 to 20,000 pounds per day were flowed. This, at an average of 15,000 pounds per day, would be 156 pounds per hand per day. Another engine- and boiler-shop has 200 men, about 35 of them in the foundery. There is one cupola with a maximum capacity of nearly 6 tons, but the average daily flow is 6,000 pounds. In other founderies, from observations and estimates, the weight of castings produced was found to range from 85 to 250 pounds per hand per day (molders, core-makers, and laborers). In one foundery of 36 men 4 tons per day are melted, an average of 222 pounds per man. As the cost of castings is usually rated by the pound, this is a very practical method of considering the matter. For small work we may establish a limit of output at which a foundery ceases to be a source of revenue. This also would serve to call attention to the importance of the value of time and to stimulate the employment of the best flasks and facilities. It is needless to say that it is in this as in other work—a diligent attention to these particulars makes all the difference between a paying and a profitless investment. In a foundery for small work, especially where hinged iron flasks are used, and in bench-molding in which machine-presses have effected a surprising saving of skill and time, a system may be mapped out by managers which may be easily followed and will give improved results, but in loam-molding no such uniformity nor mechanical routine is possible. In this, efficiency depends upon the skill and ingenuity of the molder, and the imaginative power required in getting out a complex casting with its molds and fixtures must be exercised to be appreciated. The loam-molder, like the engineer- and machine-designer, must be highly imaginative and cannot prosecute the highest arts of his craft without the possession of mental faculties of a kind in which persons with the most liberal collegiate education are often deficient.

Small castings are made in molds of green or damp sand held in flasks. The flasks are usually wooden boxes with ears or lugs and pin-holes by which they may be held together. In forming the mold several flasks may be mounted one upon another. An upper flask is called a cope, a lower flask a drag, a flask to draw out sidewise a cheek. A wood pattern is employed of a shape similar in most respects to the proposed casting, but a little larger to allow for the shrinkage of the metal in cooling, which is about one one-hundredth, or one-eighth of an inch to the foot. The pattern is divided into as many parts as may be necessary in order to take it out of the mold (after the sand has been formed about it) by the temporary removal of the cope or one of the cheeks. The lowest part is set into a drag in which its shape is formed in the sand. The upper part or parts are properly placed upon it surrounded by flasks which are filled with sand to make the impression of these parts. A coating of parting sand prevents the green sand in adjoining flasks from sticking together, so that each flask may be handled separately. They may, therefore, be taken apart, and the pieces of the pattern may be lifted out or removed. Then, being replaced in position, a hollow of the form of the casting is left into which the metal is poured through holes formed in the mold, while other and partial vents permit the escape of gas from the molten liquid through the body of the mold. To form holes in the casting, cores are made which are set into the mold separately in core-prints. If these cores formed part of the pattern it could not be lifted out of the mold. The difference in form between the pattern and the casting is that where there is a hole in the latter there is in the former a little boss or projection which forms a print in the mold in which the core rests. The cores are commonly made of sand, flour, and molasses, and are baked hard in ovens. The work of the green-sand molder is to fill and ram down the sand in the flasks so as to

make a good mold, with proper vents for the pouring in of the metal and the escape of gas. Upon the removal of the pattern the interior of the mold is carefully smoothed and finished by slicks (smoothing tools of various designs for finishing the surface of the mold), and is made ready for the pouring of the metal. For small pieces the flasks and molds may be prepared most conveniently upon raised benches, and this work is called bench-molding.

For large work and great variety of design the building and storing of wood flasks and patterns would involve great expense, and resort is had to loam molding. In green-sand molding a man of ordinary intelligence may learn to do a certain class of "straight work", especially if assisted by hand-presses, in a very short time, although the full knowledge of the craft requires a long apprenticeship, but loam molding presents greater difficulties. The molder has first to build and fashion the mold to form the under side of the casting. Upon this he has to build the pattern, and upon this an upper mold. These constructions are of brick and clay mortar for the molds, and of clay and wood for the patterns. The lower mold being built upon a bottom plate and the upper mold upon an annular or encircling cope-plate, and the clay surfaces being prevented from sticking together by black washes or other parting facings, the molds may be taken apart and the pattern removed leaving a space to be occupied by the molten metal. The sustaining plates are of iron. Surfaces of revolution are formed in the clay by sweeps of the reverse form revolving upon temporary spindles. Cores and partial patterns of wood are used in building up the pattern, as some of its surfaces cannot well be formed without. In the molds the clay is sustained by the brickwork and by pieces of iron called "gaggers" inserted in the joints of the brickwork. The gas-vents are formed by molding ropes of straw into the clay and brickwork of the mold. Sometimes it is necessary to support or steady the cores or upper molds by inserting bits of tin or iron which can not be removed and are cast into the work. These are called chaplets. After each portion of the mold is put on, its surface is partly dried by burning charcoal held in braziers of wire, or by removing the part of the mold and placing it in an oven. Provision has to be made for lifting the several parts. The bottom plate is provided with lugs over which links are passed, and these are sustained by cross-bars or crosses which are lifted by cranes. The upper surfaces of the bars are toothed or notched to prevent the links from slipping, and levels are adjusted by means of intermediate hooks with turn-buckles for screwing up. If there be a cope-plate above and around the bottom plate, it may be lifted in a similar manner, but a portion of the mold which rests over the pattern has to be provided with a pricker-plate for lifting. Such a plate has rings on top and straight and diagonal teeth below, so that the adhesion of the clay, which is partly dried by a brazier, will lift the mass below it. Pricker-plates are built into the mold. Before casting, the mold must be baked thoroughly. If possible it is lifted and transferred to an oven, and in some founderies molds of large size are built upon rolling platforms so that they may be wheeled into the oven. But the largest molds have furnaces of brick and sheet-iron erected about them with a proper aperture for the chimney. The temporary furnaces built in the floor are often large enough to contain several hundred pounds of coal. They are of simple construction, a fire-box, a grate, and an ash-pit under it, and an opening on one side of the masonry covered by iron plates which are set in to form the fire-doors. Pipes convey the products of combustion to the casing of the mold, and provision is made for the access of the hot gases to every part of the mold. For a large mold the firing is continued several days. The mold is then examined for cracks and defects, which are puttied up. It is re-set, the top plate is put on and clamped to the bottom plate, the whole mold is surrounded by a boiler-plate inclosure rammed full with sand, and the mold is ready for the pouring in of the metal, iron pipes being placed in the sand to lead the gases from the straw-rope vents to the surface.

The foregoing is a scantling of the principal processes of founding, which will be readily understood. It is almost needless to say that in the actual work many contingencies have to be met and many precautions observed which are not here touched upon. For a 4-bladed propeller there are four side or cheek molds; the hub is formed in clay, but the blade-molds are formed to a wooden pattern, one pattern being used four times. Where ribs and hubs occur upon a surface of revolution the surface is formed by sweeps and the ribs and hubs are pieces of varnished wood set in. In molding large gears machines are sometimes used for making and spacing the forms of the teeth in the mold.

Loam-molding requires a coarser sand than green-sand molding, and instead of being merely damp the sand is reduced to a mortar. Green-sand molds are often dried in ovens, especially upon delicate work, for which the molds would otherwise be too fragile to resist the flow of the metal.

Of the time required in the operations of loam-molding some idea may be gained from the following examples: For making the mold or core of a large horizontal engine frame, the casting weighing 9 tons, a week's labor was required. For a propeller of over 3 tons weight and 16 feet in diameter a molder and a helper were half a day in building up the mold under a single blade. We may imagine from this the amount of time and labor and the cost of failure in molding and casting a propeller of 24 tons weight, such as that of the Cunard steamer Gallia. The largest steam cylinder ever cast was that of the engine of the steamer Pilgrim, at the Morgan Iron works. This took 45 tons (net) of metal, which required three hours and twenty minutes to melt, but was only two and a half minutes in filling the mold, being partly flowed in from two tanks and partly poured in from large ladles operated by cranes.

In casting large work of irregular form the contraction of the casting by cooling is liable to leave portions of the metal strained, either causing the work to break in cooling or to become liable to break under service. To

guard against this Mr. Norman Wiard recommends that such castings be reheated in a brick oven and cooled slowly while covered with slack lime.

If the uniformity of product warrants the expense, loam-castings may of course be made by aid of flasks and patterns with nearly the same facility as those in green sand. In some engine founderies flasks are used for castings of the largest size, facilitating the work and diminishing the requirement of skilled labor. Loam, dried or baked in an oven, makes firmer and better molds than green sand. While, therefore, in some founderies a cylinder of a certain size may be cast in green sand, in others this size would be cast in dried loam as the superior method. But the difference in practice would depend mainly upon the convenience of facilities and the frequency of reproduction of a given form.

The rapid growth in the use of malleable iron and steel castings has been mentioned and promises to go to greater lengths, especially in respect to steel castings. By heating small gray iron or ordinary castings to cherry red in a covering of red hematite iron ore, and, cooling slowly, they become annealed and give up part of their carbon to the ore making the casting tougher and from two to four times as strong. Steel castings are much used, especially for parts requiring to be tough and strong but of shapes involving trouble in forging, particularly such as cross-heads and rocker-arms. These pieces are commonly made by parties making a specialty of this work and are supplied to engine-builders. The difficulty in making thin steel castings is due to the avidity with which the steel takes up carbon, but in the Cowing method the mold is of ground quartz, glue and flour, faced with powdered silica, and the steel cannot take up carbon from the mold, castings having been made with as little as .0007 per cent. of carbon, and which will bend without annealing. In the Chester steel process castings are first made of Bessemer steel in green sand. At first they are brittle but are annealed very much like malleable iron. The use of the Chester castings is highly approved in many classes of engine-work. There are various other processes depending upon different materials of the molds, the castings being toughened by subsequent annealing.

Blacksmithing.—In ordinary stationary-engine building the tendency during the past decade has been to contract the relative scope of the blacksmithing in more ways than one. The greater employment of steel and malleable iron castings and cold-rolled pump and piston-rods is one reason for this, and the employment of more powerful machine tools is another, so that both foundery and machine-shop have encroached upon the former province of the smithy. The blacksmith-shop is a small department of the work in the manufacture of stationary engines, especially of small engines. One man does the blacksmith work upon average on from 20 to 30 horse-power (10 inches by 20 inches) engines per annum. The blacksmith-shop of a large southern engine-works has 8 fires and a total of 22 men, of whom 6 are colored men, these acting as laborers and strikers, and not being skilled hands.

The power employed in blacksmithing is used in operating trips and steam-hammers and varies greatly with the weight of the implements used, which in turn varies with the character of the work, but in no very definitely assignable ratio. In some cases about 2 horse-power per operative is employed. Hammers are of course the principal power tools employed in blacksmithing. For small work these are built in great variety, drops and trips and direct-acting steam-hammers with ingenious devices to attain two objects, the cushioning of the blow and the regulation of its force and rapidity. By the improvement in these facilities the efficiency of labor has been greatly increased, sometimes more than doubled within the past ten years, and the precision and accuracy of the work has also been improved. In some shops a great improvement has been made in forging shafts under the drop with dies. For this work steel dies are considered too expensive, but cast-iron dies, which are easily made, suffice to bring the work so true that much labor is saved in machining. The advantage of this method is very conspicuous in making certain large sizes of graduated shafting where it is estimated to involve an eightfold advantage in the saving of time and labor, part of this being in the forging, but the greater part in the machining, there being much less metal to be removed by the slow operation of the cutting tool. On the other hand, in some shops, it is stated that the powerful cutting tools now in use are so efficient that the work from the blacksmith-shop does not require to be, and is not, forged as close as formerly.

The most powerful steam hammers in the country are found at the large works at Pittsburgh, Bridgewater, and Nashua, which make a specialty of heavy forgings, notably of marine shafts. The heaviest single shaft ever made in this country was forged under a hammer weighing $8\frac{1}{2}$ tons, with a 7-foot stroke. To the steam piston of this hammer a pressure of 60,000 pounds might also be applied to increase the force of the down-stroke.

In marine work forgings are a factor of the highest importance, and the work being large and difficult the operations are of great interest. The skill of labor required is of a different kind from that of the machine-shop. The machinist may map out the course which he wishes to pursue and test everything with deliberation, and in the machine-shop there is a large body of workmen of the same grade of skill. In forging large work there are a few men who are not only highly skilled but are invested with duties which require such mental qualities that many men would not be capable of fulfilling them. The master-hammer man on such work must not only act correctly and with a skilled perception of the conditions involved, but he must act quickly; high qualities of executive decision are involved which may not be apparent from a mere description of the processes.

The following descriptions of the work of forging heavy marine machinery are derived partly from observations, but largely from a series of very graphic and reliable descriptions which have appeared in the engineering journal,

Mechanics. All heavy forgings are handled by means of porter bars. These are shafts or bars of a size in some sort corresponding with the magnitude of the work involved. The iron is welded to them, and the forgings are thus built out from them as a basis, and they afford a means of handling the work in every stage of its progress. The forging of blooms and slabs from the scrap is a process which need hardly be described in this connection. The scrap is piled evenly upon a thick board and set into a furnace, and, when it comes to a welding heat, the mass which adheres together and is still sustained by the cinder of the board is taken out by tongs, and by means of overhead railways is run to a hammer or squeezer and reduced by blows or pressure to a compact bloom or bar, weighing, perhaps, 10 or 12 per cent. less than the original scrap. Such blooms and slabs are the raw materials of which forgings are made.

Forgings of many tons' weight are handled by a body of men (with no power appliances except a crane and a hammer) in the only practicable way, namely, by balancing. The porter bar rests in the loop of an endless chain hanging from the pulley of a crane, which pulley is hung in a swivel so as to permit of easy movement. As the work is forged on, the bar is moved to preserve the equilibrium, and to the cool end is clamped a wheel with handles by which it is turned over as it rests in the chain and while it is in process of hammering. From six to a dozen laborers turn the wheel and shift the work in accordance with the sign motions of the hammerman.

The porter-bar for the great shafts of the steamer Pilgrim was itself a shaft 15 feet long and weighing 12½ tons, each shaft of the Pilgrim being 40 feet long and weighing 81,200 pounds, or about three and one-quarter times as much as the porter-bar. The first operation is the "breaking down" of the porter-bar, which is simply heating the end and hammering it to a flattened and bulging surface upon which blooms and slabs may be laid. The blooms weigh about 240 pounds, and in forging this shaft, from 2,500 to 4,000 pounds of blooms were put on at a heat, and three hours were required for heating the larger piles. The heating was effected in a reverberatory blast-furnace, and the crane was in such a position that the work could be swung from the furnace door to the crane and back with the greatest facility. Only the unfinished end of the forging being placed in the furnace, it was not required to be very large or deep, and the opening was closed temporarily with a filling of brick and mud, except a little opening for watching the heat. As the moment for taking out such work approaches drops of molten metal are seen starting from the glowing mass and running down into the furnace. This is commonly called gravy, and is waste. It is sometimes an object to have the pieces heated of nearly uniform bulk, as there is then less waste. This shaft was forged under the directions of Mr. Dorrity, of the Morgan Iron Works. The weight of blooms used was 118,000 pounds, and the weight of shaft being 81,200 pounds, the diminution of weight is seen to have been about 40 per cent. There were 185 tons of coal used, or about 3⅓ pounds coal to 1 pound of blooms. The work involved a total of 360 days labor in 34 actual days, showing an average of 10 or 11 men per day. The value of the shaft was $10,000, or about 12 cents per pound. The blooms were made of nails, horse-shoes, and boiler-clippings, small scrap being used in preference to large. At an average added weight of 3,000 pounds per heat there would have been about 27 welding heats. A 15-inch shaft 10 feet long required 5 reheats—3 for welding or building out, 1 for roughing, and 1 for finishing, cutting off, and trimming, these last operations often requiring two heats for this size of shaft. The heats were not nearly as long as for the greater shaft, which was about 26 inches in diameter. The shaft was out only four minutes for roughing. The hammer in roughing went over it once in one minute, and a second time more slowly in two minutes, and the fourth minute was spent in straightening and alignment. Calipers with long handles are used in gauging, and a wedge-shaped implement with a handle is used in cutting off. Collars for such shafts are sometimes shrunk on, when it may become desirable that they should be removed, and sometimes they are forged upon the shaft, in which case they are made separately in halves and are heated to welding and stuck on the shaft in proper positions.

The forgings described are straight shafts, and although the work is large it is comparatively simple. In making solid crank-shafts greater difficulties are involved, and the liability to failure and imperfect work is so great that built-up shafts are now commonly employed upon merchant vessels, although in the navy and in naval contract works the crank-shafts are forged solid. It its necessary to forge upon the shaft at right angles and near together two heavy masses of metal. These are usually forged as solid masses, and are then cut out by drilling and slotting in the machine-shop so as to remove the portion of the forging between the double-crank arms. As the cooling of the forging leaves a "skin," the cutting away of these portions is liable to cause the shaft to spring out of line. The element of risk is large, and the failures in forging such work are not infrequent. Built-up crank-shafts are constructed in various ways, but commonly by shrinking the cranks upon the shafts and pressing in the pin which is made a little larger in one crank-arm than in the other to avoid binding when forced in. Solid forged crank-shafts were the prevailing practice both in Europe and America within the last fifteen years. To be sure in the earliest history of steam navigation built-up shafts were used, but these were of cast iron and comparatively small. The practice of making built-up wrought-iron shafts first gained foothold in this country and afterward in England. In 1860, Mr. J. S. Wilson, engineer for Neafie & Levy, Philadelphia, placed a built-up shaft in the steamer Saxony, which still plies between Philadelphia and Boston.

The following is a brief account of the forging of a half crank for a 14½-inch built-up shaft. The porter-bar being broken down or flattened, the crop end (that which had been cut off from a previous forging) of a shaft was first welded on. Then twelve 5- by 5- by 30-inch 240-pound blooms were welded on leaving a plain square end 26

by 18 inches. The necessary width was got by adding a slab on one side and then one on the other. Slabs being larger than blooms there is less waste in heating them. The end was worked to 42 by 14 inches when the finishing heat was taken and the crank was brought nearly to size, but somewhat wider and thicker and not necked. It was then ready for the machining. The crank was forged with counterweight, as is usual for all screw-shafts, but not for long-stroke paddle-wheel shafts.

In forging beam-straps smaller blooms are used. The most difficult, as well as one of the largest of marine forgings, is the rudder-frame. A large rudder-frame is made in eight pieces, which are afterward welded together. The largest of these is the main post, which is built out as usual from a porter-bar, with enlarged blocks for cutting out spaces for the pintles, and with offsets for the cross pieces. The back part of the frame is forged upon porter-bars to templates of wood in two pieces, and the inclined offsets coming from the main post to join them are set out by punching and cutting out a piece of the main post and throwing out the offsets by means of a taper punch, all being afterward forged and brought to a proper size. The tiller and two cross pieces are welded into scarfs of the curved back member as the work proceeds, and there then remain five welds to be made. The post is now machined, shaping the ends of the offsets and the bearings, and drilling and slotting out the spaces for the pintles. The frame is clamped together and laid on blocks, the ends to be welded being shaped into blunt wedges. The bearings are used in turning the frame upon the blocks. The welds are made by aid of a portable blast-forge and an anvil, two wedge-shaped filling pieces being welded in at each joint. The filling wedges are of sharper angles than the spaces to be filled, in order to make a sound joint in the middle. Ordinary frame parts are sometimes pieced merely by making a single V-joint, heating and hammering together.

The breakage of crank-shafts is an accident of great frequency, and one which involves in peril the lives of passengers on ocean steamers. Breakages are due to impurities, oxide, or even blow-holes spread under the hammer. They may also be due to the unequal cooling of a shaft, the exterior skin being first cooled and this preventing the interior body of metal from shrinking when it cools, so that it is less dense than the outer skin and may even be torn apart by its own efforts to contract. Breakage is also attributed to the attempt to forge large shafts under hammers which are not heavy enough for the work. The precautions which may be taken are then the careful selection and working of materials, the use of heavy hammers, the slow cooling of the shaft in slaked lime or ovens, and the forging of shafts hollow. So far as danger results from the attempt to forge very large shafts, it may be remarked that by running engines at higher speed with smaller diameter of propellers, so large shafts would not be required.

Steel shafts are also made. The largest steel shaft ever forged in this country was 28.6 feet long and 13 inches in diameter, and weighed 10,990 pounds after being lathe-turned. It was forged by the Nashua Iron and Steel Company, and shipped to Pittsburgh, Pennsylvania, for Gray's steamer line.

The cost of engine forgings varies from 7½ to 15 cents, small forgings usually costing least by the pound. Solid crank-shafts of large size cost more than ordinary forgings. Their cost is stated to range from 30 to 8 cents per pound, according to size. An estimate of the cost of a large solid crank-shaft is as follows, by the pound:

	Cents.
Material and forging (mostly labor)	16
Machining	9
Total	25

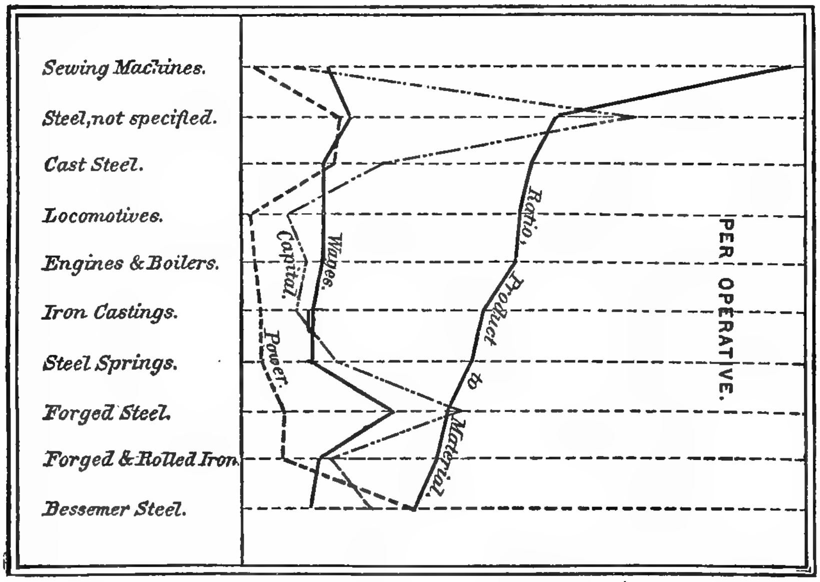


FIG. 1.—INDUSTRIAL CONDITIONS IN SEVERAL CLASSES OF MANUFACTURE OF METAL WORK.

Second item—Steel not otherwise specified.
The "per operative" rating is for wages, capital, and power.

The frequency of failure enhances the cost, and built-up shafts may not cost half as much by the pound as solid forged shafts. At the United States navy-yard, Washington, the following labor was employed in forging a large shaft: One hammerman at $5 a day, 1 hammer-tender at $1 50 a day, 6 or 8 laborers at an average of $1 25 a day. Some private concerns pay their hammermen very much more than the rate stated ($5), especially on work requiring great skill, and the failure of which would result in thousands of dollars loss.

MACHINE-PLANTS AND POWER.—The following are examples of the powers and machine-plants of engine-building shops. In one shop there are 62 men to 75 power machines, and the average length of shafting per operative is 6 feet of main and 8 feet of counter-shaft. In another engine-shop, 60 horse-power suffices to drive 80 machine-tools. The power per operative in engine-building shops usually

ranges from one-half to three-fourths of a horse-power, and per ton of machine product per year about 6 or 8 horse-power are required. The power required in machining is relatively small, especially for light machinery. A small diagram is here introduced (Fig. 1) showing, per operative, the *relative* power, wages, capital, and ratio of value of product to material for some of the most important classes of metal manufacture, as returned in 1870.

A shop making about 2,500 horse-power of engines and boilers in a year, average size of engines built about 30 horse-power, has the following machine-plant:

32 lathes.
11 planers.
7 drill-presses.
1 vertical pulley-lathe, 12-foot swing.
1 bolt-cutter.
1 centering-machine.
1 slotting-machine.
2 pipe-cutting machines.
1 horizontal boring- and facing-machine.
1 vertical boring- and facing-machine.
1 milling-machine.
3 emery-stands.
370-feet line or main shaft.
450-feet counter-shaft.

This gives an average of about 5 feet line and $6\frac{1}{2}$ feet counter-shaft per power machine.

A shop with 200 operatives, devoted almost exclusively to engine-building, has, for driving power, a "40-horse" engine, with the following power machines:

2 vertical facing and boring mills (Niles),
2 shapers (Bement),
1 slotter (Bement),
2 boring mills (Bement),
2 lathes (Chicopee),
6 lathes (Fitchburg),
5 planers,
2 pony-planers,
2 bolt-machines,

beside emery-wheel stands, drill-presses, grindstones, and punches. This machinery is extra heavy and solid for its work.

In another large shop, devoted to engine-building and mill-work, there is an 80-horse power engine, driving 101 iron- and 13 wood-working machines, the iron-working machinery being as follows and being operated by 112 men:

32 lathes, large, small, and boring.
13 planers.
4 pony-planers.
1 vertical boring and facing mill.
2 vertical slotters.
2 gear-cutters.
1 horizontel boring-mill.
4 bolt-cutters.
11 drill-presses.
5 milling-machines.
13 emery-stands.
13 grindstones.

In another large shop, almost exclusively devoted to boiler- and engine-work, a 35-horse power engine drives the following machine-shop tools:

3 large lathes,
6 medium and small lathes,
2 boring-lathes,
2 large power-planers,
2 medium power-planers,
1 pony-planer,
1 vertical boring-mill,
2 bolt-cutters,
1 vertical slotter,
2 milling-machines,

beside drill-presses, emery-stands, and grindstones.

These will serve as examples of practice. No very exact comparison is possible, because tools are not in continuous use, and in different shops different methods are applied to effect similar results.

In one instance it was found that for 468 machine-shop tools, many not in continuous use, there were used $228 worth of lubricating-oil and $1,620 worth of oil for machine cuts in a year.

SYSTEM OF MANUFACTURE.

FLOOR SPACE.—In a large engine-works the total amount of floor space was found to be distributed approximately as follows, the percentages of the whole number of hands employed in the several shops and departments being also stated:

	Per cent. men.	Per cent. space.
Machine-shops	34	30
Foundery and cupolas	24	14
Boiler- and sheet-iron shops	24	22
Blacksmith-shop	10	7
Pattern- and wood-shops	4	3
Office, warehouse, and store-rooms	4	24

For the latter, more particularly, 30 per cent. machine-shops, 13 per cent. boiler-shop, 12 per cent. foundery, 9 per cent. cupolas, ovens and storehouses, 9 per cent. sheet-iron shop, 7 per cent. blacksmith-shop, 6 per cent. pattern store-room, 5 per cent. boiler- and engine-rooms, 4 per cent. offices, 3 per cent. pattern-shop, 1 per cent. sand-shed, 1 per cent. tool-room.

There thus appears to be in floor space per man, about 130 square feet in machine-shops, 85 square feet in foundery, 140 square feet in boiler-shops, and 100 square feet in blacksmith-shops. Of course every shop will vary in these respects, some having much more foundery space per operative.

Progress of uniform methods.—In the manufacture of small mechanism prolific output with great excellence of work has been realized through study and analysis. In the manufacture of heavier mechanism the same analytic appreciation is at work. It has a harder and a greater problem, but its demonstration is merely a matter of time. Machine design is yet in its infancy, and so soon as there shall be a pause in innovation and improvement establishing more firmly the settled functions of machinery, then the time will be ripe for harmonizing the components of heavy machinery so as to effect a great industrial saving. The existing patterns of steam-engines differing in no very essential details are of a number and variety which I will not attempt to estimate. Some present special points of merit, and none perhaps are so poor as not to possess at least special points of advertisement. And some features which are highly meritorious under certain conditions of use become defects under other conditions. Were engines built singly by old and unimproved methods an indefinite number of designs might continue to be used, but in the competition of more productive and uniform methods it follows that in the course of time, and upon the expiration of patents for special features, a limited number of designs will prevail, viz, those which are most adaptable to the needs of large classes of steam users, and which are cheapest to build for good and efficient service.

Old machine-shop methods are in process of change, and the improvements are usually less suitable to the requirements of small makers and for single pieces of mechanism than to the wholesale fabrication of uniform work. Already methods which suggest those of the watch factory are in use at some of our large engine-shops, and engines of considerable size are built in lots of 10 with the employment of standard gauges and templates. Workmen are employed to repeat a given operation upon great numbers of parts, and where this can not be done the work is classified by its likeness, and one workman is kept upon one class of work. For example, let us consider the work of planing. There are in a room, say, 20 or 30 planers operating upon a much greater number of different parts of machines. If the manager or foreman be unable to keep one planer running at one speed on one class of work and under one man, he exerts his ingenuity to come as near this desideratum as possible. The better he is able to succeed in such matters the more exact is the workmanship and the more profitable the manufacture. Further than this, the machinery so made, other things being equal, commends itself to a greater number of purchasers, and under enterprising oversight the large demand reacts to insure better facilities for uniform work.

The attempt to gain valuable time by systematizing work is an attempt to diminish the time, not of actual machine tooling, but of setting, waiting, and preparation; and an inquiry into the actual time of machine operations reveals the great amount and importance of the portion of time not occupied by the actual tooling. In machining gun components we may easily estimate by number of parts turned out in a day, and such estimates are made the basis of wages; but in the large work of machine-shops there must be a large and ill-defined allowance of time for setting and waiting. Making an estimate of time spent in actual machine tooling upon work, we find that it must be doubled, trebled, or quadrupled in many cases, in order to account for the total time. Herein lies the value of handy tools in which American shops excel, and of which many examples might be cited. I will mention one. Messrs. William Sellers & Co. build a lathe in which the screw and hand-wheel motions are displaced by a device which does the setting by a single motion of the hand. Such a device may at first sight seem trivial and of no great advantage, but when we estimate the number of times in a day a machinist has to perform this motion, and the aggregate saving of time, we find that upon some classes of work it has a money value which is not to be despised. Such handy appliances also help the spirit of the workman, and stimulate him to alacrity in the performance of his work.

In time of setting and waiting, also, lies the great difference in cost between large work, or work which can be done piece after piece of the same kind, keeping one workman on one job, and work which involves a new essay of preparation, adjustment, and experiment for every successive piece. Thus in making pulleys of one size in large lots, and in making various parts of engines in small lots, there is a vast difference in cost of work by the pound. The value and productive power of labor can best be maintained by close attention to shop system, and a convenient tool, kept in good working order, may involve as great a saving as a rapid-acting tool.

Interchangeability in machine-work.—Interchangeability in machine work has made as much progress as may be expected under conditions of change. It involves stability, and stability, while desirable in itself, is a bar to further progressive development. It is a practice like the freezing of water, tending to prevent further flow. That it already exercises such an influence may be noted in some instances. The introduction of metric measures meets its most serious opposition in the existence of standard tools and gauges whose proportions are only commensurate with the inch system. So, too, improvements in certain classes of machinery have to be very deserving to gain a foothold where existing standards would be disturbed by them.

In machines, interchangeability demands the best patterns as a guarantee against changes which would impair its value. For a single piece of mechanism it might not be worth while to enter into so close a study of the proportionment of the several parts singly or relatively as to secure absolutely the best results, but when the machine is designed to be duplicated by thousands and for an indefinite period of time, it is expedient to have a design well worth maintaining.

Some degree of interchangeability prevails in the transmissive machinery of factories. The shafting, pulleys, and hangers in a mill, as has been well pointed out, constitute a great machine, generally much greater and more expensive than any single machine employed, and not only so, but a machine which is used in every class of manufacture and may properly have many of its parts and fittings interchangeably duplicated in all.

A highly important move was made in furthering uniformity in general machine-work by the adoption of an American standard screw-thread. This standard, with standard bolt-heads and nuts, was proposed by Mr. William Sellers, and adopted by the Franklin Institute December 15, 1864, and by the United States Navy in 1868, and it is now the acknowledged standard of American practice, so well known and approved that it may be regarded as part of the groundwork upon which future developments in interchangeability will rest.

"Inch-divided lead screws", says Mr. Coleman Sellers, "are common to all lathes in all parts of the world". The crystallization of practice in the uniformity of shop sizes, based upon the inch, forms a growing obstacle to the introduction of metric units. Whether or not these units are desirable in their application to machine-work, almost the whole weight of American practice seems against them. This practice has unquestionably led in many advances above old-world methods, and the same judgment of the fitness of things which has stimulated departures from former practice by American machinists seems to incline them to hold to their present convenient units and shop sizes rather than to sacrifice them for conformity with the less desirable systems of countries whose machinery is less uniform and no more accurate than theirs. As used, the beauty of the inch system is in its customary division into convenient aliquot parts, eighths, sixteenths, and sixty-fourths, nor is the decimal system, where it appears convenient, necessarily sacrificed. A 10-foot pole is a convenient implement, but a 10-meter pole could not be handled readily, so that in any case convenience would require that the metric system should be broken by non-metric divisions. In like manner a thousandth of an inch is a recognized standard in fine gauging and jeweler's work. A draughtsman desiring to make a drawing to a reduced scale would naturally and easily make it one-half, one-fourth, or one-eighth full size, but if he did so with metric measures his dimensions would often come in decimals of three or four places, and to make his drawing one-tenth or one-fifth scale would be decidedly troublesome. In

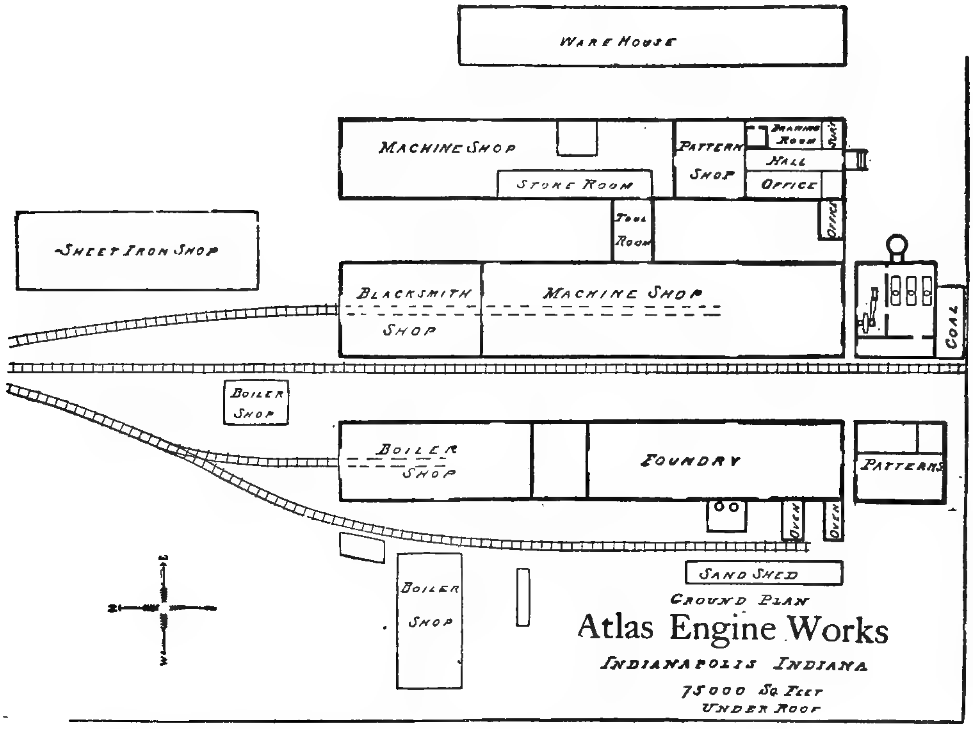


FIG. 2.—PLAN OF ENGINE WORKS.

short, the handy units and convenient multiples and divisors which the so-called inch system has are lacking in the metric system. Machinery involves proportions as well as mere aggregate measures. The metric system, though competent to register such measures, cannot be made to express with convenience these natural and useful proportions unless indeed new divisions be introduced, making it also like the inch system, a mixed system.

Interchangeable gearing has forms of teeth by which wheels of any size, from one having the smallest practicable number of teeth up to a rack, and having the same pitch, may be made to work truly together. Some time since, Mr. F. A. Pratt, of the Pratt and Whitney Company, Hartford, Connecticut, observing that gear-wheels were the only important element in machinists' work which had not been reduced to a satisfactory system for making interchangeable parts, applied his attention to devising such a system for cutting gears. This interchangeable

system is founded upon a carefully studied series of templates and cutters for a series of diametral pitches covering all ordinary requirements with sensible accuracy. Uniformity is maintained by finishing the cutters by means of templates in a pantagraphic milling- or edging-machine, the templates being formed in an epicycloidal milling-machine, in which the motion of the cutting-mill is guided by means of wrapping connections upon surfaces representing pitch and describing circles, the whole system and its appliances being the result of ingenuity and careful study, while it may be considered a noteworthy step in the advancement of interchangeability in mechanism. The diametral pitches and other involved dimensions are the usual inch and fractional dimensions.

Arrangement of shops.—The Atlas engine-works of Indianapolis, Indiana, is one of the best systematized establishments of its kind in the country, and the plan of the works here presented shows a carefully studied arrangement. The works are located in the open country, with unlimited room, and nothing to prevent a good arrangement of shops. They are also exclusively devoted to the manufacture of engines and boilers, not including, as is often the case, the manufacture of milling and general machinery. The plan will explain itself, but we may specially note the arrangement of tracks on which a small locomotive is employed for moving work and bringing in materials. Except the small house for the storage of patterns, which is in two stories, the works are entirely upon the ground floor, while in some shops in crowded quarters in cities, the buildings have three or four stories.

In founderies and machine-shops, jib-cranes are in most common use, and we will sometimes find such a crane near each of the largest pieces of machinery, but more usually a few large cranes sweeping over extensive areas. Traveling cranes are not as commonly in use, but permitting, as they do, the utmost freedom in moving from any part to any other part of a shop, they are to be commended for increasing facility of work. They are

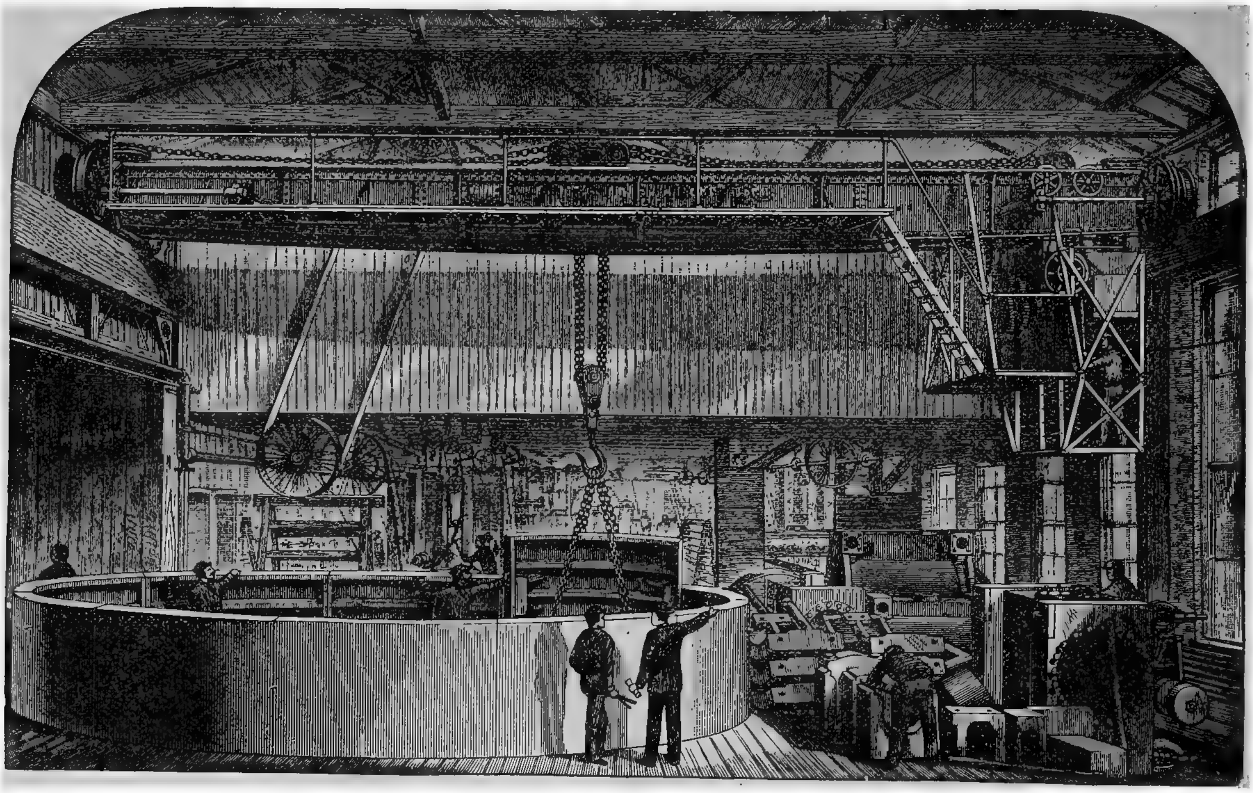


FIG. 3.—POWER TRAVELING CRANE.

used in some large works, for example, in the machine-shop of the Morgan iron-works. In Fig. 3 is shown a power-traveling crane. This is of a type built by the Yale Manufacturing Company, Stamford, Connecticut, with improved devices for traversing the bridge on the tracks and the trolley on the bridge. These cranes are used by the Harris Corliss works, Providence, Rhode Island; the Chicago foundery company, Erie City iron-works, and other establishments. The highest capacity as yet built is twenty tons, and the greatest span of bridge is 71 feet.

In Fig. 4 is shown a jib crane in a foundery. The outer end of the jib has a truck with wheels moving on a circular track. This dispenses with the ordinary strut, and the jib beams, being supported at both ends, permit a larger space to be reached for the same load and strength of beams than with the ordinary jib. These appliances appear to comprehend a large shop in one machine. Their convenience is manifest, and their employment rapidly increasing, registers a notable industrial advance.

Overhead railways or transfer tracks are used in forge-shops, boiler-shops, and other places where the work has always to be moved in one path, and their utility in establishments of systematic arrangement is sufficiently obvious.

At the works of the Hartford engineering company, manufacturers of Buckeye engines, the arrangements for handling heavy parts deserve mention. In a central yard there is a very large (25-ton) steam-crane, with a jib 53

feet long. This is surrounded by one-story shops, over portions of which the crane sweeps. In the roofs and ceilings of these shops are five large trap-doors, one over the heavy lathes, one over the planing and slotting machines, two over boring-mills, and one over the erecting-shop. Thus engine parts weighing fifteen tons or more may be turned, passed to the machinery for planing and slotting, and thence to the boring-mills, and finally placed in position for erecting or assembling the parts together, all by the sweep of a single crane in the fraction of a circle. Auxiliary to this arrangement are a number of traveling cranes with trolleys, in sections of the shop reached by the large jib-crane. These traveling cranes serve to convey work to tools beyond the trap-doors, and are required only in portions of the shop.

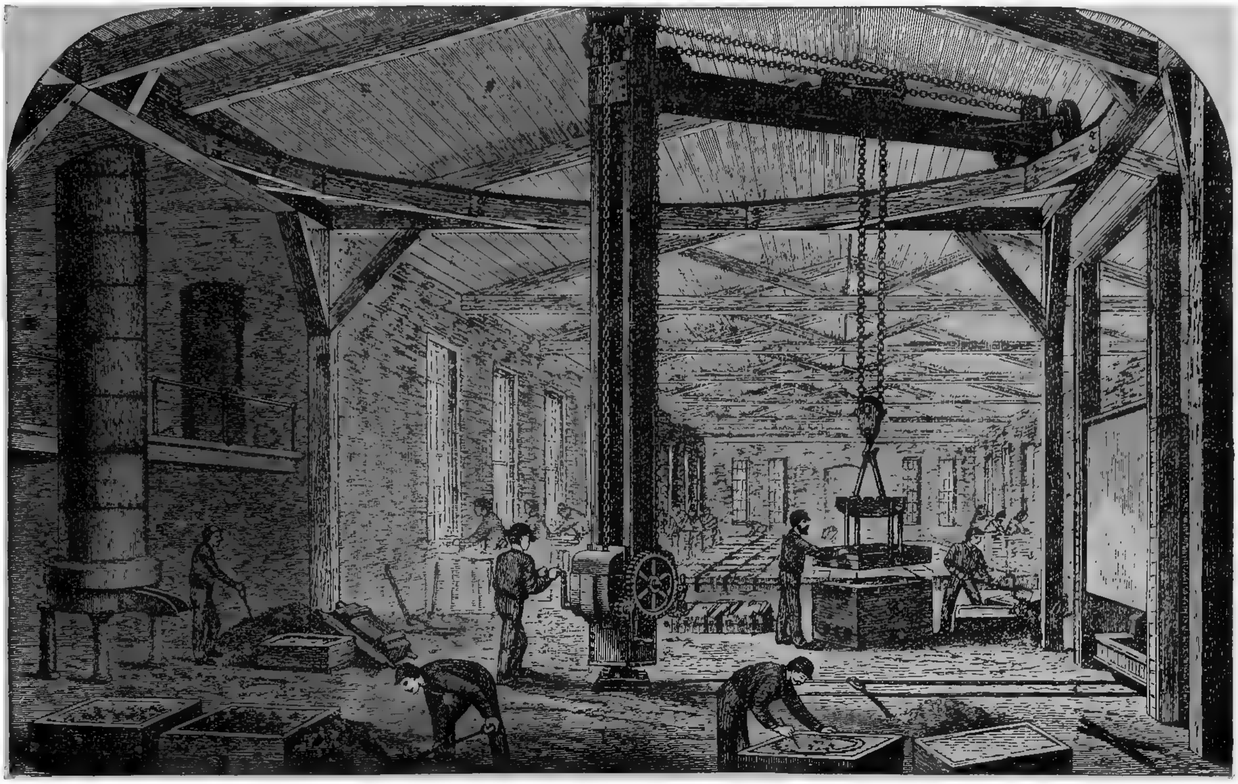


FIG. 4.—HAND TRAVELING CRANE.

Handling tools and drawings.—As an example of the methods pursued at the Atlas Engine works, the system of handling tools and drawings may be cited. It is in many respects similar to that in use at the Baldwin Locomotive works. Such system, although its details may seem simple, is a feature of no mean importance and one too much neglected in many shops. It saves time, worry, and confusion, and prevents misunderstanding and loss. In watch manufacture on a large scale it is often hard to draw the line where book-keeping ends and machine-work begins, and the details, specified as follows, are a proper part of the machinery of management in engine works:

Tools are taken out by checks. Each machinist has six checks, and when he takes out a tool the check is placed in the case from which the tool is taken. In reference to drawings, the originals are kept in a large office-vault, and for shop use tracing-cloth copies are provided, fastened on boards and shellaced. The shop copies are kept in racks, and when a drawing is given out to a machinist, the tool-room keeper pulls down a vertical slide-plate like Fig. 5, with pins on which are hung numbered lists of the drawings in each rack. One of these lists is shown in Fig. 6. They are backed with board, and the machinist's check is hung upon a pin opposite the number of the drawing taken out. The attendant then slides the plate up out of sight and the record cannot easily be disturbed. This may seem a very simple provision, but as a single slide-plate may furnish a complete index and account for between 500 and 600 drawings, it is really a labor-saving provision which has a real money value.

In the like details of many other machine-shops, efficient systems prevail. In the shops of the Hartford Engineering company all drawings are made upon sheets of two or three uniform sizes. These are traced for office file, and blue prints for shop use are taking from the tracings and mounted on boards. The consequence is that a drawing may be referred to as easily as one would turn to the page of a book, and the whole record of machine details for a wide range of work is comprised in the contents of a very small chest of partitioned drawers. Without this system, or with the old lack of system, most draughtsmen know how much space is occupied by drawings of different sizes and descriptions, unclassified odds and ends worn and tattered by continual turning to find some detail secreted under the heap. Many of these mechanical drawings involve a cost of labor no less than would be required by meritorious oil paintings of equal surface, and their proper handling is is enough to mark the difference between good work and poor work, or between profit and loss.

Assembling.—The fitting and setting up of large engines is not usually done in such a uniform and continuous manner as to admit of exact estimates of the time and labor required, but it is found that 10 men will erect 14 10 horse-power horizontal portable engines and boilers in a week of sixty hours. In this case the demand for the product was so great that the machinery was being built and set up continuously week after week. The time of course did not include any part of the boiler making, but only the assembling of the boiler with engine and framing parts.

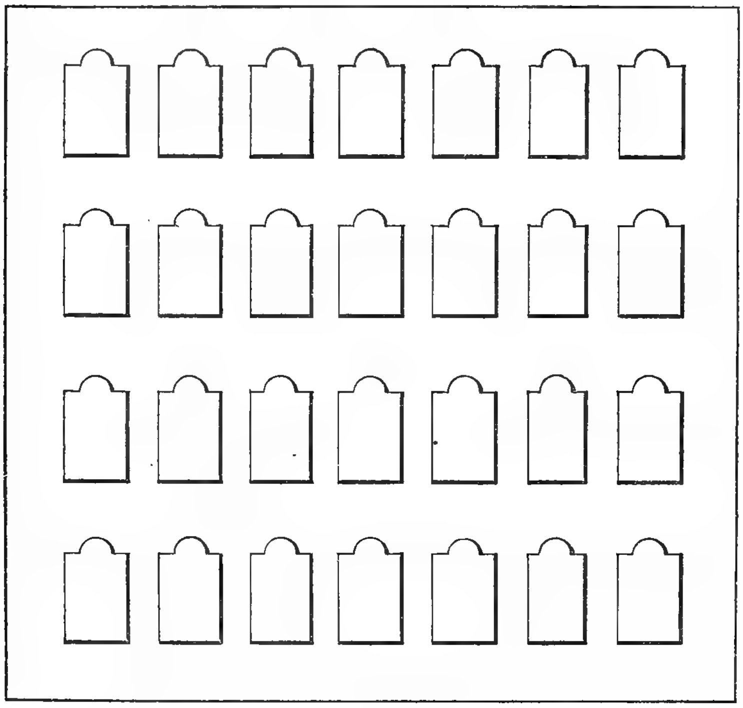


FIG. 5.—DETAILS OF SYSTEM FOR CARE OF DRAWINGS.

Shrinkage may be properly considered in this connection. It is a method in frequent use. Cranks are shrunk upon crank-pins and shafts, straps are shrunk upon beam-centers, deadwood rings are shrunk upon marine shafts, collars are often shrunk upon shafts, rims upon wheels, strengthening-rings upon hubs and bosses, and so on.

In shrinking a 15½-inch crank-pin into marine cranks, less than one-sixty-fourth inch is allowed for shrinkage of the diameters. The method employed is as follows: The cranks are blocked up, edges upward, on a boiler-iron floor, laid over a 6-inch layer of loam, so that a fire may be built about them. They are brought to a red heat by a wood fire, built in a temporary casing of boiler plates. After the fire is removed and the holes are swabbed out, the cranks are laid faces up, the pins are set in, and the companion cranks, similarly heated, are laid over and surrounding the pins, being kept in proper place by parallel distance-blocks laid between the upper and lower cranks. All the work is trued from the faces of pins and cranks, and care must be exercised in blocking up the parts, so as to secure parallelism and correct centering All the heating that deadwood rings require is simply obtained by standing them on end and kindling an open wood fire about them. These rings are of brass and rest in brass and lignum-vitæ in the deadwood of the steamship.

In shrinking, a slight allowance is made for contraction by making the hole a little smaller than the piece to be inserted would be if both parts were cool. Without this allowance the pieces will be loose, but a more common difficulty is due to giving too much allowance, in which case the eye contracts so powerfully upon its seat or shaft that it becomes cracked and strained near the seat, and thus losing its hold becomes loose as before, the grip of the eye being permanently destroyed. It is easy to heat and slide on a ring or strap which will certainly break apart in the contraction of cooling, and it usually requires less than one-eighth of an inch allowance to do this. Some examples of allowances for successful shrinkages are: One-sixty-fourth of an inch scant for a 16-inch pin or shaft, (another) one-one-hundred and twenty-eighth of an inch for a 16-inch pin or shaft, and three-one-hundred and twenty-eighths of an inch for a 26-inch shaft. Probably even smaller allowances would make good shrink-fits, while larger would be liable to injure the eye.

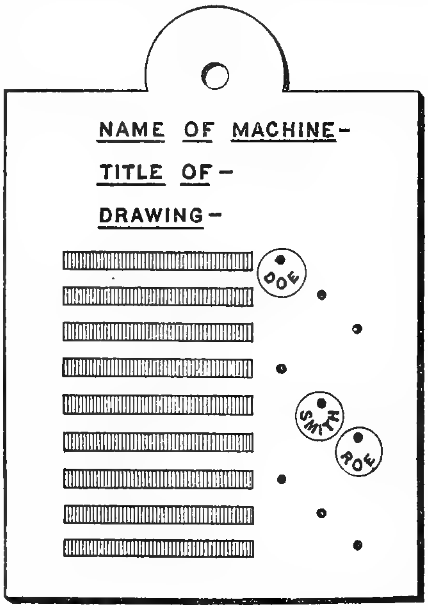


FIG. 6.

Planing.—Planing and drilling are the principal work on engine-frames. The time required in planing the frame of an 8- by 12-inch engine is ten hours, of a 16- by 30-inch engine of the same style twenty hours. Twelve hours were spent in planing the frame of a 10- by 20-inch slide-valve engine of another make. The surfaces are gone over twice, rough and finish, the latter with a three-eighth-inch feed. The Sellers planer, operating with 3 or 4 tools, actually does three times as quick work as an ordinary planer in planing upon the frames and cylinders of steam-pumps.

In planing the frame-feet of an 18- by 42-inch Corliss engine five hours were spent, these feet being given only one cut. Five hours also were required in planing the bottom of a 10- by 16-inch (cylinder) plain slide-valve engine-frame, a single cut being given.

Forty hours were required in rough and finish planing the frame of an 18- by 42-inch Corliss engine cylinder, this being done on a 54-inch planer.

In machining built-up cranks the keyways are first slotted, and wooden keys are used in them to assist in the subsequent work. The cranks are first planed to thickness. Then scribe-lines are punched in them and they go

to the slotter, where the edges are finished to the desired profile. The slotting-tool is fed with water or soapsuds and takes a chip $1\frac{1}{2}$ inches wide and one-quarter inch thick in machining a large crank.

Links are machined in various ways. For making small links, the Greenwood planer-chuck, with curve-cutting attachment, is a convenient tool. Special machines are sometimes used for making links. They may also be slotted to shape, or may be turned in a vertical mill, or planed to a pattern.

Ordinary rough and finish cuts in planing are made with round-nosed tools. The second-cut tool is wider than the first, and the angle between tool and surface is slightly smaller. The velocity is usually the same for both cuts, ordinarily 20 feet a minute, or 4 inches a second, but sometimes as slow as 13 feet a minute. A first cut on a Pratt & Whitney planer, with a "rooter" or round-nosed tool, was noted to be one-thirty-second inch deep, and the speed was 16 inches in 4 seconds. The ratchet had 28 teeth, with 4 revolutions per inch of screw, and 4 teeth were fed, giving a cross-feed of one-twenty-eighth of an inch. Other planing cuts noted in soft cast-iron, speed 33 inches in 6 seconds: rough cut, one-sixteenth inch deep, one-sixty-fourth to one-thirty-second inch feed; finish cut, one-thirty-second inch deep, one-thirty-second to three-sixty-fourths inch feed. In general, rough cuts run from one-sixty-fourth to one-eighth inch feed, according to tool and finish; finish cuts, one-sixty-fourth inch upward, sometimes with flat tools as much as $2\frac{1}{2}$ inches. In work which requires any degree of finish two cuts are always necessary. It is considered that, with proper management, no work ought to require more than 3 cuts. The final surface-cut on a fine plate was made with a flat-nosed tool, 1 inch feed and one-one-hundredth inch depth of cut.

For planing short cuts shaping machines are useful, but the length of cut is limited by the firmness necessary for accurate work. Under 16 inches traverse tolerably accurate work may be done with an ordinary shaper.

Turning.—The manner of turning one of the great shafts of the "Pilgrim" was as follows: The shaft was drawn from the forge-room to the machine-shop by aid of a steam-winch, and it was then lifted and carried by an overhead traveler. It needed no straightening. The lathesman found centers and tested the centering by four lines drawn along the side of the shaft at the four sides. The centering was done by a half-inch drill followed by a flat countersink, the same angle as the centers (77°), and $2\frac{1}{2}$ inches in diameter at the largest end. The shaft, 40 feet long and weighing 81,200 pounds, was swung upon centers, without other support, while a narrow place in the middle was turned up to take a cast-iron bearing-block for the support of the weight during the 170 hours which the turning required. The lathe used had a head-spindle only 7 inches in diameter and a $5\frac{3}{4}$ inches tail-spindle. The crank-seat was turned three-one-hundred and twenty-eighths of an inch larger than the crank-eye for shrinkage.

There was not as much work in machining this shaft as upon a much smaller, solid forged crank-shaft of the following dimensions: length, 16 feet; diameter, 15 inches; center shaft to center crank-eye, 18 inches. This required 300 hours' work in machining, largely turning, but also drilling, slotting, cutting-out, and planing.

Forged weight, 11 tons; removed by machinery, 2 tons; finished weight, 9 tons. The cutting-out between the cranks removed much of the weight. The shaft was held between the centers without center-rest or steadiment. In built-up crank-shafts, after the cranks and pins have been shrunk on, it is customary to assure the truth of the shaft by a light finishing cut.

The following relates to the turning of a very large fly-wheel by Watts & Campbell, Newark, New Jersey. The wheel was built in 7 sections, and had a weight of 49 tons. Its diameter was 25 feet, its face, 7 feet 6 inches, with 3 crowns, on which three 24-inch belts were to run. In turning this wheel the lathe ran two weeks night and day, say, two hundred and eighty-eight hours. One revolution occupied nearly 6 minutes, and 5 tons of chips were removed from the surface.

In machining a large pulley fly-wheel 10 feet 4 inches in diameter and 30 inches face, sixty-four hours were required, the operations being the turning of the face (2 cuts), the facing off, and the boring out of the hub.

In the shops of William Sellers & Co., Philadelphia, pulleys are rapidly rough-turned by a lathe in which five tools work side by side. A special apparatus is necessary, in order to obtain uniformity of bearing and avoid discontinuous cuts of the several tools. The finish cut is made with a single tool going over the whole face of the pulley with a feed of from one-half to three-eighths of an inch. Of the speeds of turning tools, the following notes were taken in one shop:

	Material.	Per minute.	
		Revolutions.	Speed.
			Feet.
18-foot pulley	Cast iron	$\frac{1}{4}$	14.13
18-inch pulley	do	$3\frac{1}{2}$	16.48
8-inch shaft	Wrought iron	8	16.75
2-inch shaft	do	32	16.75
1-inch valve-rod	do	64	16.75
$\frac{3}{4}$-inch spindle	Steel	64	12.64

Drilling.—The work of drilling upon a Corliss engine-cylinder is full twice as much as upon a plain slide-valve engine-cylinder of the same size (as stated in a shop where both styles were built).

There is about five hours' work of drilling on each frame of a plain slide-valve engine between the sizes of engine which may be designated, from their cylinder dimensions, as 8 by 12-inch and 16 by 30-inch engines.

The speed of twist-drills is stated in velocity of periphery at 15 feet per minute for steel of usual temper, 20 feet per minute for wrought, malleable, and cast iron, and 25 feet per minute for brass and the softer metals

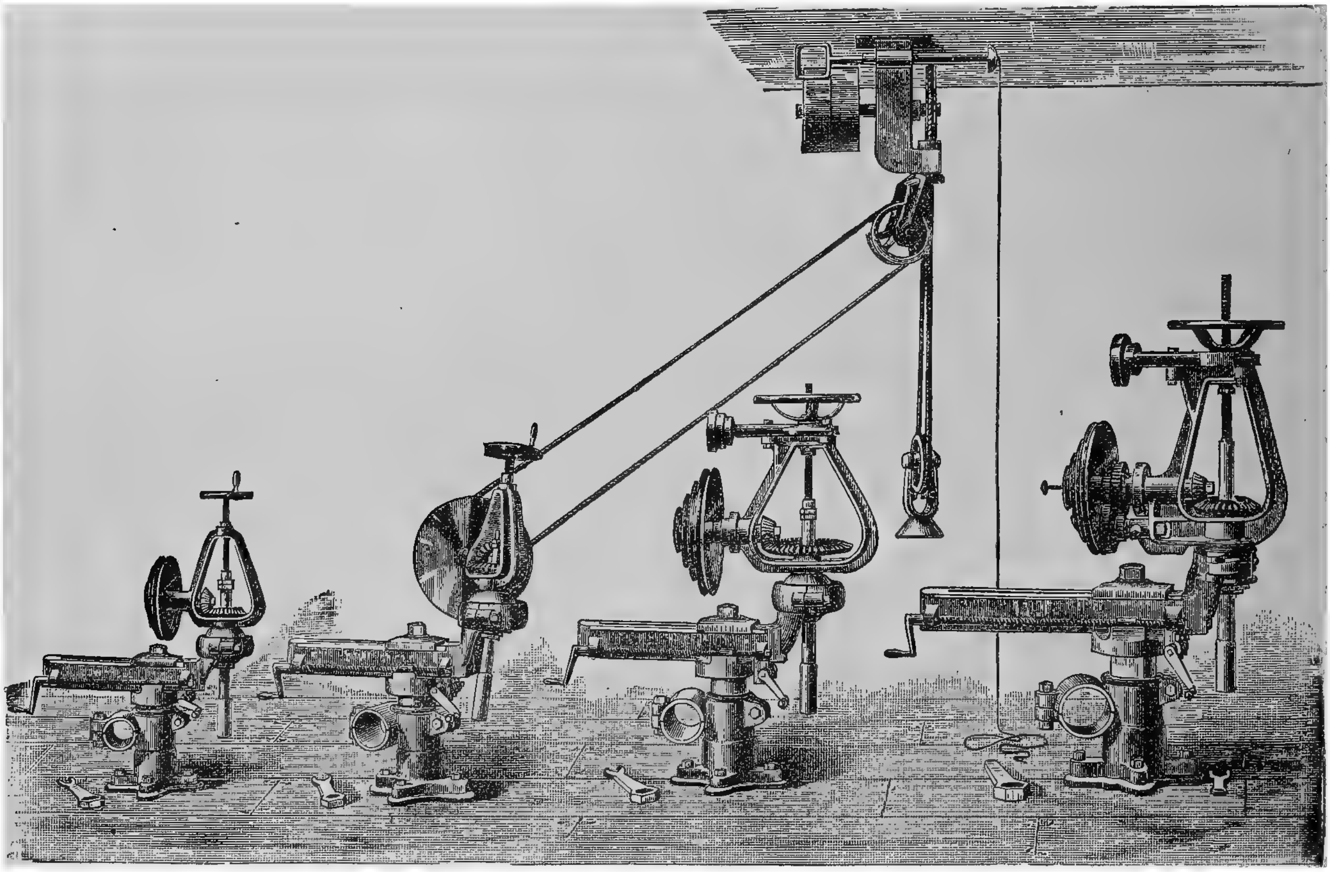


FIG. 7.—PORTABLE DRILLS.

These speeds are based upon a soft temper of the metals as is usual. The use of belted drills permits higher speeds with less shock than the use of geared drills.

The importance of having tools which are convenient to handle as well as rapid in action has been elsewhere dwelt upon. In engine-building, and especially in the erection of marine and other large engines, perhaps no tool is more handy or more generally used than the Thorne and De Haven portable drill. For castings of 200 pounds and over, and holes from three-eighths inch to $2\frac{1}{2}$ inches, the portable is more convenient than a fixed drill. It is illustrated in Fig. 7, from which the drill is seen to be driven by a leather cord, so that it may be placed at any desirable distance from the countershaft, the surplus connection being taken up by a straining pulley and weight hanging in a bight of the cord. It is also mounted in a spherical joint, so that it may be inclined at any desired angle. On hurried work, one man with this drill does ten or twelve times as much work as a man with a ratchet-drill. At the Fulton Iron Works (Gerard B. Allen & Co.), Saint Louis, one man with one of these tools drilled in a circle of about 7 feet, with a $1\frac{1}{2}$-inch drill, 22 holes 2 inches deep and 10 holes 3 inches deep in 5 hours. This was at a rate of about one-fourth of an inch a minute with 32 changes of work. The drill does a work equal to that of 12 men with ratchets, as men ordinarily work, or the work of at least 6 men working at their best.

Boring.—In boring an 18- by 42-inch Corliss engine-cylinder twenty-four hours are required for two cuts, the finish being slower than the rough cut. The finish feed is about one-eighth of an inch. We may note here, as remarked under the head of locomotive manufacture, that the Seller's machine bores cylinders, faces flanges, and counterbores cylinders equal to the largest locomotive size in three hours and a half, the usual time having previously been over thirteen hours here, and twenty to forty hours in foreign countries. The Wheelock apparatus for reboring cylinders, without removing the back cylinder-head, will rebore sizes of 8 to 24 inches in diameter in from eight to twelve hours.

The boring of a specified pair of large cranks is described as follows: After slotting the cranks to profile, they are put under a vertical boring-mill and the eye is bored for the crank-pin. A $4\frac{1}{2}$-inch flat drill is first run through the cranks. This permits 4-inch boring-bars to be passed through them. The upper ends of these boring-bars are keyed in to the vertical spindle-socket and the lower ends run in collars in the bed-plate of the mill. The boring-tools are double-ended, and each end takes a cut an inch deep, with a slow feed. The tools are keyed into

the boring-bar. By three through cuts the hole is bored from 4½ to near 15½ inches. The finish cut is made dry, the previous cuts having been made with soapsuds. The shaft-holes are bored in an entirely different manner. A slotted cross is used, with stave-shaped tools, which make an annular cut, and take out a solid core of metal. The finish boring of the shaft-seat is not made until after the crank-pin is shrunk in.

Machining small parts.—In this work milling machinery is sometimes used. The small parts being required in comparatively small quantities, are not produced with anything like the cheapness of small gun and sewing machine parts. Keys, which, if made in large quantities, might be cheaply made, as made, are usually quite expensive, and other small parts, straps, link-blocks, liners, and the like, if manufactured as small hardware, in quantities, would cost, in some cases, no more than one-eighth of their cost by slow machine-shop methods. A small key, for example, is rated at $1 50, as made in the shop; that is to say, it costs ten times as much as a butt-plate or a lock-plate, and three times as much as a complete bayonet—parts of a gun as large, or larger, than the key, more elaborate in form, and requiring as much and as accurate machining. Such comparisons convey an idea of the advantages of uniformity of design and large manufacture, which is not without its lessons. A valve cross-head for a small engine consists of a cylindrical piece of steel bored through in two dimensions, there being a step in the bore, and on the side of the piece is a boss or hub, with a drilled hole. One man makes 20 of these in three days, spending one and a quarter hour on each. The work is done on a lathe, and consists of facing and rounding 3 ends, drilling 2 holes, and drilling and counterboring 2 holes for each piece.

In some cases highly economical results are obtained by finishing machine parts by grinding instead of filing. This is done upon the surface-grinding machine, which appears in some respects like a planer, the work being fastened upon a reciprocating bed and passing under an emery wheel which has a cross-feed and vertical adjustment and is driven by a drum at the back of the machine, like the spindle of an edging-machine. As a substitute for filing it saves the files and is claimed to save three-fourths of the labor. The machines, as made by the Brown & Sharpe Company, will grind 36 inches long, 14 inches wide, and 13½ inches high.

BOILER-MAKING.

Estimates.—The following estimates of time, labor, and material are derived from actual practice under the various conditions stated, and are believed to cover very fairly the various kinds and circumstances of work. They are reduced to averages of weights handled per man per year as the most available unit of comparison, although a number of men are employed in the construction of every boiler.

In making stationary (horizontal tubular) boilers one man may be said to use in a year 9½ tons boiler-plate, 3½ tons tubes, two-thirds ton rivets, about 27,330 pounds material per year, and about 90 pounds per working day. Again, the average output per man per year in another case is 7½—"8 horse-power," 3,600 pounds boilers, or 5—"20 horse-power," 6,000 pounds boilers. The following is a more specific estimate of the material and labor in building a standard form of return tubular boiler without fire-box:

	Pounds.
Weight of 50-inch shell, 14 feet long, about	3,000
Weight of 50 3-inch tubes, 10 feet long, about	1,500
Weight of 1,000 rivets, about	90
Weight of castings in the boiler, about	210
Total	4,800

The time of labor upon this boiler is forty-eight days. Four or five men were employed continuously in building it, and it was completed in ten days. The pneumatic power riveter of the portable type was used in the work.

In making ten "10-horse power" horizontal portable boilers, three hundred days of actual labor were expended upon the ten boilers. Their aggregate weight with tubes, fire-boxes, and water-bottoms was 37,000 pounds. The average was thus about one boiler per man in 30 working days, or about 123 pounds handled per man per working day. The pneumatic portable riveter was used.

It is said that, while with hand work only, it is a good day's job for three men and a boy (rivet-heater) to drive 35 pounds, or 250 rivets per day, with the portable power-riveter one man and a boy can drive as many as 105 pounds (from 750 to 800 rivets) in a day, while rivets are sometimes made at the rate of 8 per minute.

Let us now turn to marine work. An engineer engaged in building marine boilers states that they cost about 10 cents per pound for all but the smallest sizes, which cost more, of this 6 cents being rated for labor and 4 cents for material. This estimate, it may be noted, makes no mention of investment and profit, which are taken with the labor, the actual manual labor upon the boilers costing 2 or 3 cents per pound. The following is an estimate of the weight, work, and cost of a marine boiler:

	Per cent. of weight.
12,250 pounds plating, at 4 cents per pound	57
3,860 pounds castiron, at 3 cents per pound	18
1,850 pounds forgings, at 4½ cents per pound	9
3,540 pounds tubes and rivets, at 4½ cents per pound	16

	Cents.
Estimated cost of labor per pound	2½
Estimated cost of material per pound	4
Estimated cost of investment per pound	3½
Total cost per pound	10

About two hundred and thirty days' labor were involved in building this work, upon portions of which power riveting-machines were used.

The following is an estimate of the cost of construction of a rectangular compound marine boiler of 60 tons, government work, hand-riveted in place and requiring much flanging:

Material, 60 tons, at 7 cents per pound	$8,400
Labor, 20 days, by 22 men	9,600
Total	18,000

The work involved reduces to 4,400 days per man. The daily labor by crafts and wages paid was as follows, the average rate of wages for skilled and unskilled work being about $2 20 per day:

2 boiler-makers or fitters, at $3 per day	$6 00
2 flange-turners, at $3 per day	6 00
6 riveters, at $2 25 per day	13 50
3 rivet-heaters, at $1 50 per day	4 50
6 caulkers, at $2 25 per day	13 50
3 helpers, at $1 50 per day	4 50
Wages per day	48 00

The total cost of boiler being 15 cents per pound; the cost of labor was 8 cents, and of material 7 cents per pound.

Machine plant and machine methods.—In boiler-making the number of pieces of power machinery are not numerous as compared with the machine-shop plant. In one establishment a 25 horse-power engine operates 4 blacksmith-shop tools, 4 tumbling-barrels, 1 blower, 8 boiler-yard tools (punches, shears, riveter, and rolls), 1 air-compressor for riveter, and 2 hoists. Some of this machinery is, as will be seen, for foundery and general purposes. A boiler-shop with an annual output of two or three thousand horse-power of stationary boilers has the following principal machinery: 2 punching-machines for boiler-plate, one with spacing-table and apparatus attached; 1 machine for scarfing or planing boiler-plates on the edges; 1 set rolls for boiler-plate. Hand-riveting is the practice in this shop.

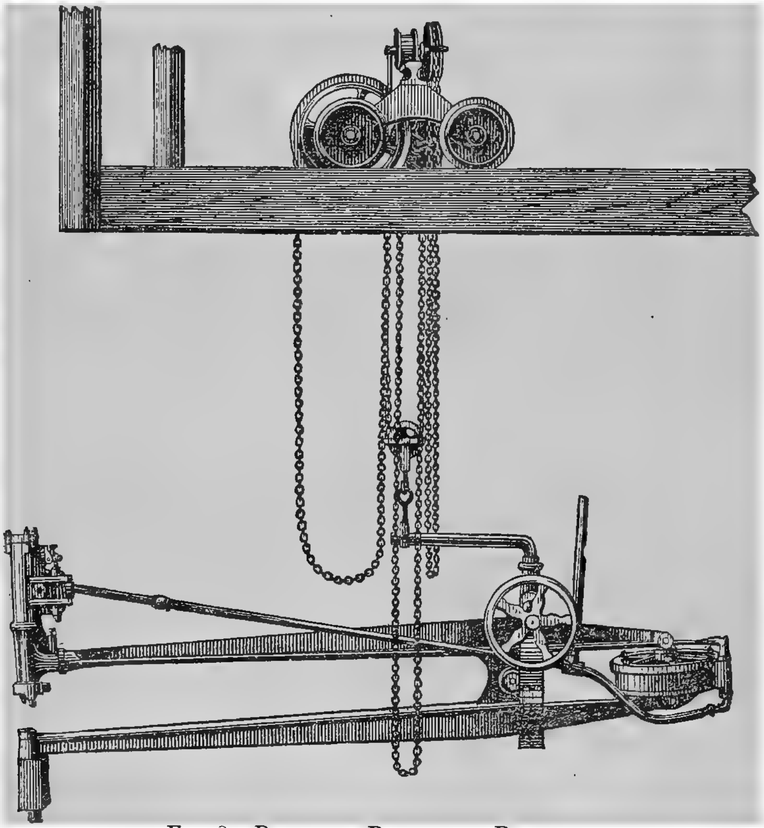


Fig. 8.—Portable Pneumatic Riveter.

Another shop with a considerable number of operatives has 2 punches, 1 pair shears, bending-jaws, and straightening-rolls. Most of the operatives are employed in setting up, holding iron plates for punching, ratchet-drilling, marking out and riveting (all of which is done by hand).

Many large shops, especially in the south and west, rely upon hand-riveting, but steam, hydraulic, pneumatic, or other power riveters are being rapidly introduced, and with such manifest advantages that their general employment is only a question of time. A size of riveter made by Wm. B. Bement & Son for large work is called a 72-inch riveter, the distance from the center of die to the bottom of opening being 6 feet. The stake or anvil member of the riveter is made of a superior quality of wrought iron in order that it may be made small enough to permit the riveting of small flues. The riveter has a balanced steam-valve, and the steam which drives the rivet is made to return the piston to beginning of its stroke before escaping.

A stationary riveter employed at the Globe Iron Works, Cleveland, Ohio, under 50 pounds steam strikes a 40-ton blow.

For work on stationary and portable boilers the portable pneumatic riveter is becoming a favorite tool, being approved by some of the most reliable manufacturers, such as Lowe & Watson, Lane & Bodley, Griffith & Wedge, the Atlas Engine Works, and many others, as furnishing better work and a productiveness greater (by about 4 to 1) than that of hand labor. The Allen pneumatic portable riveter usually operates with the boilers in a horizontal position, instead of being hung vertically from cranes as with the fixed riveters. It is claimed that with hung work the portables can be operated by fewer men than the fixed machines, that they make tighter work, and drive with equal rapidity. An illustration (Fig. 8) is presented of this riveter, showing it suspended from an overhead

track. It may be shifted to various positions, and is often used in connection with a peculiar saddle of rollers so that the boiler may be turned readily in making cylindrical joints. The rollers are turned by a gear-wheel, and have holes or pins by which they turn the boiler working either with the rivet-heads or the punched holes of the boiler. (In hand-riveting such work the boiler rests upon the long beak of an anvil extending within the shell,

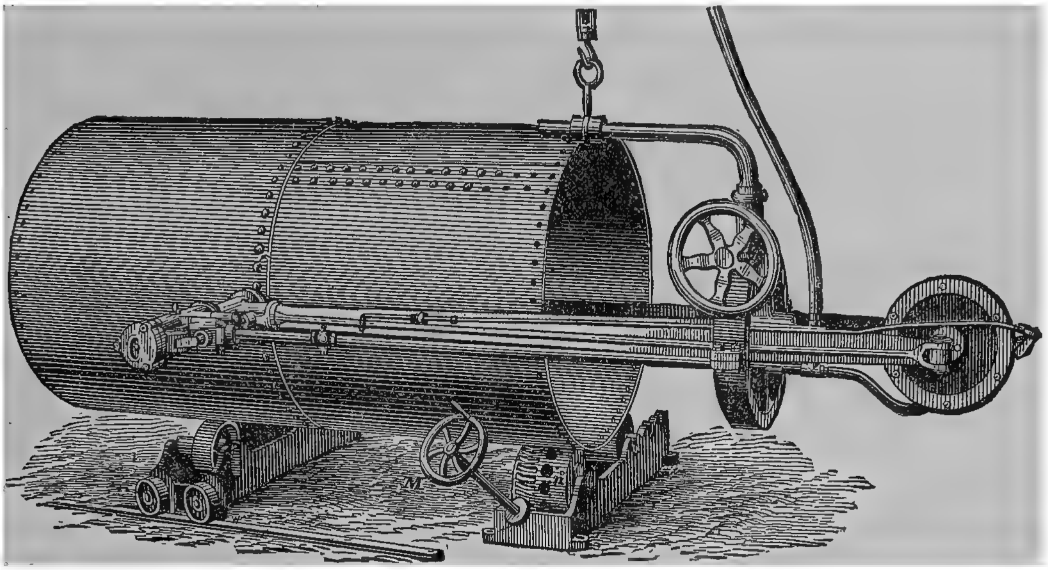


FIG. 9.—MANNER OF HANDLING BOILERS IN RIVETING.

while an endless chain from a crane above passes around the outside of the boiler and enables the workmen to shift its position from rivet to rivet.)

The operation of the pneumatic portable riveter may be briefly described as follows: The riveter consists of two long levers held at their axis or fulcrum in a ring with a worm-wheel so as to work in any axial position. One end of the apparatus has a pressure-cylinder between the lever-arms, the other end a pressure-cylinder with piston and riveting-hammer on one arm and a die or anvil on the other. The machine first closes upon the plates, flattening the burr before riveting, and it then presses them with about 1,200 pounds pressure while the rivet is being driven. The rivets are formed, not by a single blow, but by a succession of blows, as in hand-riveting. The riveter makes from 150 to 200 strokes a minute; it forms the head of a three-quarter-inch rivet in six seconds, and easily finishes two rivets a minute. A rivet-boy places the rivet and lets the pressure into the large cylinder which closes the lever upon the plates. Then an operative admits pressure to the hammer-cylinder and the rivet-head is formed. The machine saves the labor of two men, one riveter and one for holding the work.

In the air-compressor used with this riveter, the steam- and air-cylinders are in line and have the same bore and stroke, 7 by 7 inches. The valves have a positive motion and the reciprocating parts are made designedly heavy.

So far as I can ascertain, the use of riveting-machines is no more advanced in England than in this country, some machines of American manufacture being used in England. Both fixed and portable machines are, however, in use in the north of England shipyards.

The multiple plate-drilling machine of Thorne and De Haven is employed for drilling boiler-plates and mud- and fire-box rings. This machine is described under the head of locomotive manufacture, but the general introduction of such machinery is prevented by the fact that work is not of a sufficiently large and uniform character to warrant the expense. The British board of trade allow such advantages in the inspection of drilled over-punched boilers that it is made an object to incur the extra cost of drilling, and in the large marine shops in England boilers are commonly drilled in place. Considering that in this age of steam a person traveling or dwelling in a large community is scarcely ever out of the range of liability to injury from a boiler explosion, anything which affords greater security is an object of general concern. In this country boilers are usually punched, but for convenience and rapidity of execution American drilling machinery is unsurpassed and will undoubtedly work its way into more extended use. On some classes of straight work it is claimed that with the use of multiple drills holes can be drilled about as rapidly as they can be punched singly, but under ordinary conditions (although it is not easy to make exact comparisons) drilling boiler-plate may be said to cost about five times as much as punching.

Spiral punches have been used which do not strain the iron as much as an ordinary punch, and to obviate the well-known loss of strength due to punching, holes are often punched small and reamed out to full size; or after punching holes full size, the plates are sometimes reheated and cooled slowly, annealing the iron and restoring its strength. In connection with punching machinery many shops have improved labor-saving facilities in the way of shifting- and spacing-tables. The more primitive method of handling pieces of boiler-plate was to rest them upon an ordinary table or hang them from a crane, while half a dozen or more laborers gathered around to move the plate under the punch.

Flanging machinery is more generally used in England than here. It is costly, and operating as it does by means of formers, it is only applicable to a uniform character of work. But its employment is very desirable, for hand-hammering even to a former (common practice) strains and corrugates the iron. Iron of a grade which cannot be safely flanged by hand-hammering may be easily handled with a flanging-machine which turns the edge by an even and uniform pressure.

Ten or twelve years ago the steel manufactured was too brittle and treacherous for boiler-plates, but it is now made (low steel) of a quality ductile for flanging and admirably uniform. Its use ordinarily gives an advantage in the neighborhood of 10 per cent. in lightness for the same strength as iron. At present we even hear of cast-steel boilers and boiler parts, and the next decade will probably witness some important modifications of present practice in the use of metals in both engine- and boiler-making.

WEIGHT OF ENGINES.

In stationary engines for manufacturing purposes there is great variation in weight both for similar powers and for similar capacities of cylinder. Some long-stroke, automatic cut-off engines weigh twice as much and cost about three times as much as throttle-valve engines of the same cylinder capacity.

It might be expected that for the same cylinder capacity engines having the greatest cylinder surface would weigh most, but there are many exceptions to this rule, even in engines considered of similar strength and design. A long-stroke engine, having a longer crank than one of short stroke, has usually a higher bed, which requires increased weight.

A table is presented showing ranges of weights usual in stationary engines. Many heavier engines are of course built, but the table exhibits the ordinary range of weight. In column A are given a series of cylinder capacities in cubic feet; in column B the ratios of length of stroke to diameter of bore for the several cylinders. In column C are stated the ratios of number of square inches interior cylinder surface to each cubic foot of cylinder volume. It will be seen that these ratios of surface to volume decrease so rapidly with the increase of cylinder capacity that the difference due to proportions of cylinders is often obscured. In the columns D, E, F, G, H, J, K, and L are given weights of engines in pounds per cubic foot of cylinder capacity. Columns D and E give these weights for automatic cut-off engines, the engines alone, and columns G and H for the same engines, with the usual weights of fly-wheels added. Columns F and J give the weights per cubic foot of cylinder for a plain slide-valve engine, without and with the fly-wheels respectively. Columns K and L show the weights per cubic foot of cylinder for two designs of slide-valve engines with pulley fly-wheels.

In some engines the progression of sizes is arranged so as to get a large number of sizes with a small number of patterns by repeating the use of particular parts in several sizes. This, of course, causes a slight redundancy of weight in some of the sizes. But, even where there is a separate design for every size, the weights per cubic foot of cylinder often vary from any uniform rate of progression. I note one case, in a series of slide-valve engines of similar design, in which the cylinder capacity of one size is increased by one-fifth in the next with scarcely any increase in weight.

A.	B.	C.	D.	E.	F.	G.	H.	J.	K.	L.
0.09	1.60	1,632								8,888
0.13	1.33	1,594								7,231
0.19	2.00	1,487			6,053			8,684		
0.23	2.33	1,392	9,130			13,478				
0.27	1.71	1,257			4,352			6,296	8,518	
0.31	2.00	1,241	7,742			11,613				
0.34	1.50	1,182							8,235	5,412
0.41	1.75	1,103	7,073			10,975				
0.46	2.00	1,092			5,522			7,500		
0.52	1.88a 1.55b	1,039a 1,004b	6,346b			9,808b			6,538a	
0.59	1.77	980			5,212			7,118		5,424
0.63	1.40	947	5,873			9,048				
0.66	1.68	938							6,818	
0.72	1.60	916			4,965			6,944		
0.81	1.80	892	6,584			10,244			6,913	
0.91	2.00	863	6,153		4,022	9,450		6,264		6,044
0.99	1.64	819							6,667	
1.18	1.50	771							6,610	
1.20	2.00	791	5,250			7,916				

A.	B.	C.	D.	E.	F.	G.	H.	J.	K.	L.
1.31	1.66	748	5,649		4,278	8,703		6,183		4,962
1.57	2.00	720	4,904		3,668	7,452		5,860	6,289	
1.78	1.43	667			3,264			5,168		
1.99	2.00	669	4,322			6,834				
2.13	1.72	639	4,789		3,061	7,840		5,023	5,868	
2.36	3.00	671		5,085			7,627			
2.48	2.00	620	4,436			7,177				
2.79	1.50	576			2,361			4,337	4,838	
3.06	2.00	577	4,346			6,634				
3.48	1.87	549			2,529			4,253		
3.53	1.33	527			3,656			5,241		
3.72	2.00	540	4,032			6,264				
3.74	3.00	576		4,216			6,631			
3.82	1.44	517	4,188			6,361				
3.93	1.76	523							3,944	
4.35	1.20	491			3,149			4,736		
4.42	1.66	499			2,920			4,638	4,525	
4.72	1.30	479	4,237			6,356				
4.88	2.63	517		4,508			6,762			
5.30	2.00	479	3,585			5,472				

A.	B.	C.	D.	E.	F.	G.	H.	J.	K.	L.	A.	B.	C	D.	E.	F.	G.	H.	J.	K.	L.
5.45	1.50	461	......	......	3,234	......	......	4,964	......	......	9.22	1.91	397	......	3,471	......	......	5,206	......	......	......
6.19	2.33	450	......	3,937	......	......	6,037	......	......	......	9.66	2.00	393	3,105	......	......	4,658	......	......	......	......
6.53	1.80	442	......	......	......	......	......	......	3,829	......	10.54	2.18	387	......	3,416	......	......	5,123	......	......	......
7.06	2.66	438	......	3,966	......	......	5,949	......	......	......	12.57	2.00	359	3,174	3,182	......	4,773	4,773	......	......	......
7.25	2.00	433	3,448	......	......	5,103	......	......	......	......	14.74	1.85	338	......	2,992	......	......	4,477	......	......	......
7.62	2.10	428	......	3,674	......	......	5,512	......	......	......	15.71	2.50	345	......	2,896	......	......	4,550	......	......	......
8.71	2.40	418	......	......	......	......	......	......	......	......	18.44	2.31	323	......	2,657	......	......	4,175	......	......	......

CYLINDER CAPACITY AND COST.

The following diagram exhibits comparatively the relations of cylinder capacity, weight, and cost in steam-engines of the horizontal plain slide-valve type, rated at from 8- to 100-horse power.

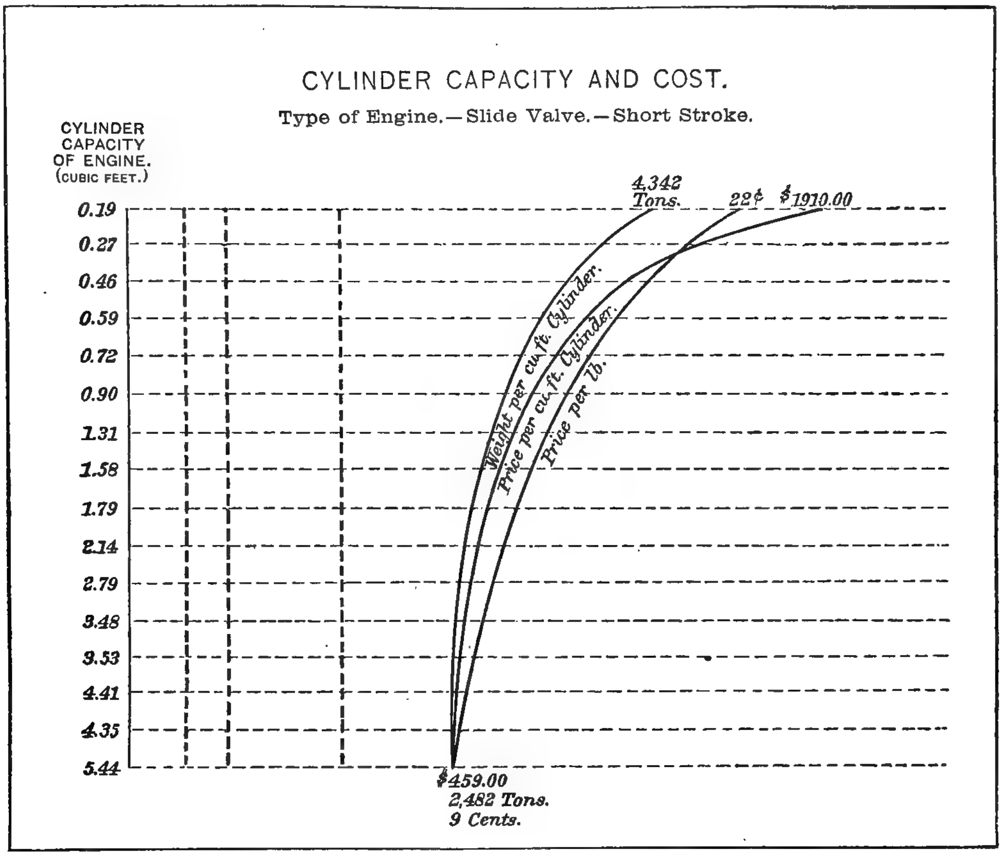


FIG. 10.

The column of figures at the left represents the cylinder capacities of the engines in cubic feet. One line shows the fall in price per cubic foot of cylinder capacity from $1,910 per cubic foot for 0.19 cubic foot to $459 per cubic foot for 5.44 cubic feet. Another line represents the decrease in weight per cubic foot of cylinder capacity from 4.342 net tons per cubic foot to 2.482 net tons per cubic foot. A third line represents the decrease in price as rated by the pound, being from 22 cents for a 0.19 cubic-foot engine to 9 cents for a 5.44 cubic-foot engine.

For ready comparison the three curves are started at one point, the three base lines corresponding with the values stated.

The prices of the engines, as per the following table, are seen to increase less rapidly than the cylinder capacities:

Capacities.	Prices.	Capacities.	Prices.
0.19	$362 90	1.79	$1,133 07
0.27	375 84	2.14	1,217 06
0.46	511 98	2.79	1,386 63
0.59	561 68	3.48	1,569 48
0.72	627 84	3.53	1,796 77
0.90	674 10	4.41	1,975 68
1.31	926 17	4.35	2,248 95
1.58	1,017 52	5.44	2,496 96

It is obvious that no formula can truly exhibit the relative decrease of price and capacity which does not consider the actual sizes of engines compared. The examples cited present an unusual degree of uniformity, a line of engines rated at uniform piston speed, and of similar excellent workmanship and finish. Between different styles and qualities of engines there can be no very definite comparison.

After we have passed the limit of equality of stroke and diameter, long-stroke engines usually weigh more, but short-stroke engines usually cost more by the pound for the same cylinder capacity and workmanship. For the same cylinder capacity, a finely-built closely-fitted engine may cost twice as much as an engine of inferior workmanship.

In attempting to discuss in general the most profitable ratio of expansion, based upon the size of cylinder and cost of engine, as well as upon the cost of fuel, it is very easy to make formulas, but these may only serve to perplex the tyro by opening for him a road of scientific investigation which leads to no useful principle or result. The longevity of an engine of the best present workmanship and material is unknown; neither material nor quality of work can be adequately expressed by formula, and the cost of repairs, an element increasing with the age and service of the engine, can only be guessed. The exact determination of the so-called point of economic cut-off could be of utility only at one time, viz, in the selection of an engine, while cost of fuel and rates of interest are subject to variations from time to time, and the work required to be done varies considerably in every case. As these variations more than cover the difference in economy between an engine of the greatest efficiency and one of less efficiency at a cost so much smaller as to more than compensate for the loss, the determination of the minimum is useless. It is useless to the manufacturer, for he must build many sizes of engines; useless to the owner, for his investment is already made; useless to the buyer, for it can not cover the flexibility of his future expenses and requirements.

There is an inherent fallacy in introducing commercial cheapness into a formula upon the same basis as engineering efficiency. Economy is a question of absolute costs and not of the relative costs of fuel and machinery. For example, the lower the cost of the engine the greater becomes the relative cost of fuel, and the earlier within limits it might be argued, may be the cut off economically employed. But, as a matter of fact, we find the best engines of fine workmanship, liberal capacity for the speed, and of high cost for a given cylinder capacity, in sections where fuel is dearest, and cheaper and poorer engines in sections where fuel is cheapest. A minimum of expense, based

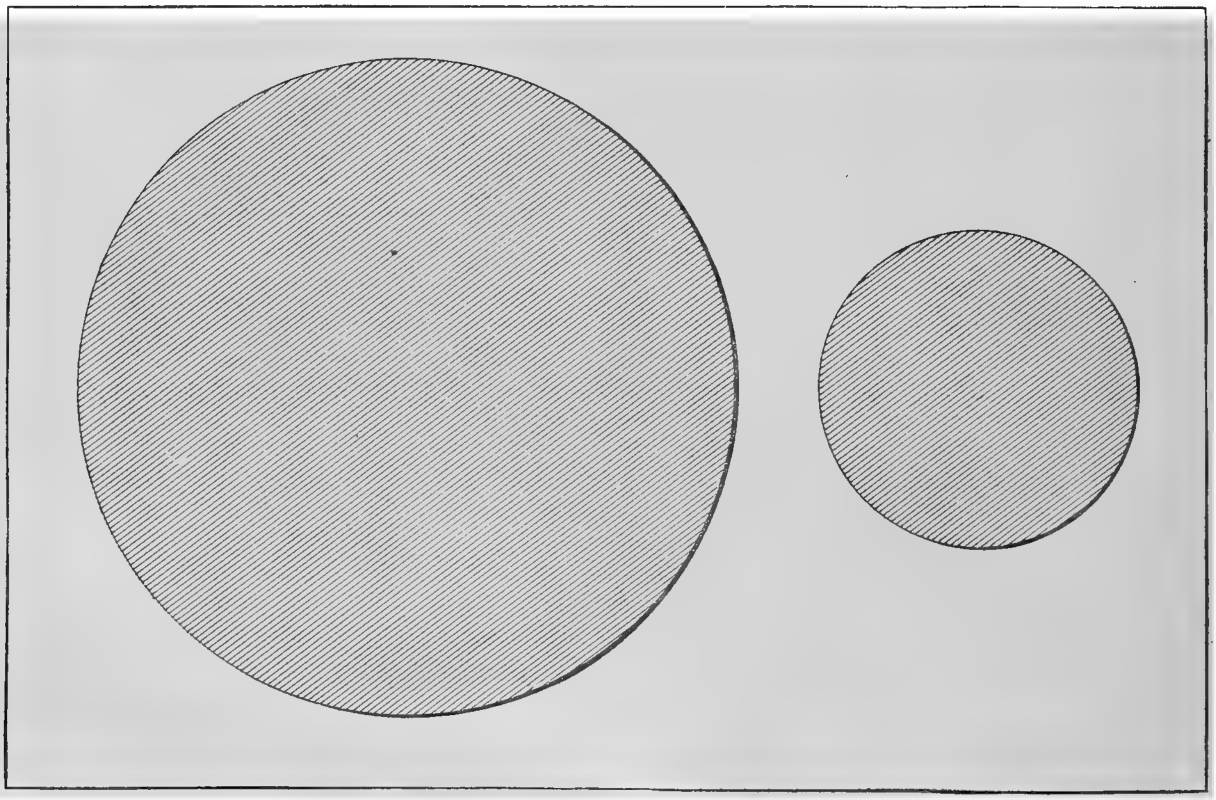


FIG. 11.—SIZES OF HIGH AND LOW SPEED SHAFTS.

on cost of engine and ratio of expansion, can not be practically established on account of the neglect of the element of quality, an element which enters into both terms of the cost, being directly as the first and inversely as the running cost, and definitely assignable in neither. Cost also depends so much upon differences in automatic valve-gear details and general finish that such variations are often enough to obscure considerable differences in cylinder capacity. The manufacture of one of the best and most economical engines ever designed (the Babcock & Wilcox) has been abandoned on account of high cost of construction, and some of the most recent forms of automatic engines have no more parts than plain slide-valve engines.

THE SPEED OF ENGINES.

Fifty years ago American mill-work was modeled after the foreign practice of that time, the shafts being of wood and square in section, with cogs wedged fast, and barrel-pulleys or wooden drums clamped upon the shafts. The earliest iron shafts were also made square, but these were displaced by round iron shafts, to which cast-iron pulleys were keyed on, (*a*) the pulleys being sometimes halved. Heavy, slow-moving shafts have been gradually displaced by light, high-speed shafts, the number of revolutions per minute having advanced from 30 in 1822 to upwards of 200 in 1880. "The practice of high-speeded shafts and the entire substitution of belting for gear-wheels belong essentially to this country".—(Sellers.) The substitution of belting for gearing in the transmission of power enables a higher speed and smoother motion to be realized and at less expense. More rapid velocity permits the use of lighter shafting. To give an idea of this, a small sketch is presented (Fig. 11), showing approximately the relative cross-sections of shafts transmitting a given power with a given factor of safety (which for mill-shafting is necessarily a high one). The larger shaft may be taken as running at 30, the smaller at 300 revolutions per minute. The change in speed being tenfold, the weight is reduced to considerably less than one-fourth.

The following is an account of one of the earliest cases of the introduction of (then) comparatively high-speed shafting displacing the old square shafts: Colonel Roswell Lee, superintendent of the Springfield National Armory, obtained the services of some very good mechanics from North's pistol factory in Middletown, Connecticut, among them, Nathaniel French. In 1831 and 1832, shortly before Colonel Lee's death, a new shop was erected at what are known as the Springfield water shops, and Mr. French was intrusted with the duty of designing the motive machinery. In place of the cumbrous square shafts then in vogue, he put in everywhere small round shafts and spindles (about half the previous diameter), to the great concern of old mechanics, who predicted that some of the smaller shafts would "wear out in a month", a prediction which, it is needless to say, was by no means realized.

The improvement in the saving of power by the use of light transmissive machinery can hardly be reckoned. In the aggregate it is enormous, and advances are still being made in this direction. Only within a few years it was the general custom to sell pulleys by the pound, with every inducement to the maker to load shafts with as much cast iron as he should think conscionable. When some enterprising manufacturers started out to put upon the market a form of cast-iron pulley designed to be as light as was compatible with the necessary strength, some argument was required to dispel the prejudice in favor of superfluous weight. Now, however, greater lightness is secured by making pulleys with wrought-iron rims. These pulleys, as made by the Hartford Engineering company, have cast-iron hubs and spokes, the arms or spokes being straight, light, and more numerous than usual, and with bracket offsets at the ends, about which the sheet-iron rims are bent, and to which they are riveted after drilling. They are faced and finished on grindstones, specially arranged with automatic feeds, so that the work is rapidly done, and the greater expense of turning is obviated. The resulting pulley is very light, and a development in the direction of higher speeding. It may also be noted that iron pulleys with wood rims are being introduced in some classes of service, for the sake of lightness.

For mill purposes the first double-acting engine in New England was built in 1808 by Philip Allen, and in 1833 Z. Allen introduced, at the works of the Wadsworth Steam Engine company, the engine with variable cut-off valves governed by a revolving ball-regulator for the expansion of steam. The Corliss engine works were started in 1848. It is not here proposed to enter upon so wide a subject as the history of the steam-engine, but in noting these early changes in shop practice the influence of the introduction of types of engine is important, and Rhode Island appears to have been the pioneer state in this march of improvement. Higher speeds first resulted from improved engines and machinery, and the tendency is still strong to push to the utmost the advantages of high rotative speed in engines. Some of the more conservative builders maintain that with the present weight and strength of materials high speeding is not in many cases economical. But, on the other hand, it is claimed that the tendency to use smaller cylinders and more rapid movement promises to go to much greater lengths in the future, and since the velocity of engine travel is still far within the velocity due to the pressure of steam, there is no practical limit to speed within that due to the weight of parts. The question of speed is a relative one, the low speeds of to-day being equal to the high speeds of earlier times, and clearly illustrating a tendency which has not reached its limit.

In engines of the Corliss type a certain speed is advantageously reached, and the excellence of this engine is such as to challenge a halt in the advocacy of higher speed. The Corliss engine, compound condensing, and with steam-jacketed cylinders, if run with tight valves, at the medium speed available with a drop cut-off, at this time may be justly considered the criterion of high economy in steam consumption. But speed is a highly economical factor. It reduces the weight and cost of machinery very greatly for the same power and economy of steam. Its value as equivalent to that of high pressures and compounding is well expressed by Mr. H. A. Hill (Boston):

> Experiments with three boats of the same size by the United States Government gave about 32 per cent. of steam condensed per hour at an initial pressure of 40 pounds in a single cylinder engine; about 26 with 70 pounds initial in a single cylinder, and about 6 per cent. in the high-pressure cylinder of a compound engine, while the low-pressure cylinder of the same engine showed about 27 per cent., an average of about 17 per cent. in the two cylinders of the compound engine. Now of these methods of economizing, one at least, that

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a Wooden pulleys are still in use at Springfield armory, Massachusetts, and in some drop shops, and are again becoming an article of manufacture for special uses.

of the higher pressures, gets its results mainly from the fact that it puts the required power into a smaller cylinder with less condensing surface. Increase of speed does precisely the same thing. It does the required work with a smaller cylinder, and so less area to condense the steam.

We naturally credit the low-speed engine with the greater durability, but high speed results in such a reduction of stress that it is easy to provide bearing surfaces much more ample for the same pressure than those which may be provided for a low-speed engine. By the laws of solid friction the advantage would then appear to be with the high speed; but the advantage of low speed, even with a greater pressure per square inch, is that there is more time for conducting away the heat of friction. To reap the advantage of high speed the lubrication of the bearing surfaces must be well maintained, and if methods of cooling fail, the disastrous effects come more quickly under high speed. But with proper engineering precautions the durability of high-speed engines is surprising. Mr. J. W Spangenberg, Warren, Ohio, has called the attention of the writer to the service of direct-attachment saw-mill engines. These constitute an exception to the low speeds of early practice, and pains have been taken to verify from several sources the statements of the remarkably high speeds of engines for saw-mills as used many years since.

The following account of one of these engines is given by Mr. C. Strom, Bristolville, Ohio:

The engine is 9-inch bore, 12-inch stroke, running a direct-attachment saw-mill. We run it all the way from 400 to 600 (1,200 feet lineal) and perhaps 700 revolutions per minute. We run some of the time a 60-inch saw, part of the time a smaller one. We can cut 1,000 feet of 1-inch boards in one hour, and think the engine with 75 or 80 pounds pressure will do more than that. The engine has been in use over 16 years, and has been run the greater part of the time, in fact almost continuously. The cylinder was bored once only in this time, about 7 or 8 years ago, and since then one set of new piston-rings has been put in. The bearings are all in good order, with all the original brasses except those on the cross-head and on the main wrist of the crank. These two have been replaced as they got worn loose in the straps. These brasses are lined with Babbitt metal. The slides or ways are *not worn at all.* The cross-head is lined with Babbitt metal, which has to be replaced occasionally, perhaps once a year. The engine is governed by the sawyer with a sawyer's or butterfly valve. We use now a half pint of good cylinder oil per day, with an automatic oiler. Before this we used a common old-fashioned oiler, the cylinder *running dry half the time.*

The engine has always run smoothly, but runs more easily with the automatic oiler.

A (10-inch bore by 12-inch stroke) saw-mill engine used by Snyder & Son, of Piqua, Ohio, has run over 8 years, averaging a million feet of hickory sawed per year. It has turned out 15,000 feet in 10 hours. It runs at 600 to 1,000 feet per minute with the saw in the log, 200 to 300 feet gigging back. It requires 1 quart of cylinder, 1 quart of engine, and 1 quart of black oil per week. In the 8 years the only repair has been one new set of piston-rings, the engine continuing to run smoothly without reboring of the cylinder or replacement of the connecting-rod boxes.

Apart from these exceptional cases, high-speed engines driving the main shaft direct at 125 to 175 revolutions per minute were used 18 or 20 years ago (1860), and for saw-mill muleys, as stated by Mr. J. W. Thompson, over 30 years ago (1850). Most flouring-mills and saw-mills were formerly run by throttling-engines of long stroke and low rotative speed, and these were largely superseded by short-stroke throttling-engines, which are in turn giving place to automatic engines.

Apart from all question of automatic cut-off, comparing throttling-engines, the advantages of high speed are immediately shown in reduced fuel consumption and boiler capacity required, so that a high-speed throttling-engine well governed and proportioned for its load may exhibit a good showing compared even with an automatic engine.

About 1850 the Corliss engine began to be introduced with great results in the economy of fuel, due to its automatic control of the admission of steam. The invention of George H. Corliss, its valve-gear principle became adopted by numerous builders of engines both in this country and in Europe. No other device has given greater prestige to American engineering. The engine is more extensively used for stationary purposes than any other type of large automatic.

The next move was to secure higher speed by the use of positive cut-off valves for automatic control of steam admission. This, like the Corliss cut-off, was a distinctive development of American engineering skill. The Porter-Allen engine was brought into prominent notice at the Paris exposition (1867), and the Buckeye engine was a design developed a few years later. At the Paris exposition high-speeding received another aid in the introduction of Richards' improved indicator for testing the power of engines. The Porter-Allen engine derives its name from the combined inventions of John F. Allen and Charles T. Porter, the admission valves being the invention of Allen, and the general design of the engine due to Porter, whose name is associated in particular with the governor and the framing or bed of the engine, both of which have been largely copied. The Buckeye engine was developed mainly under the patents of J. W. Thompson. The device of a "shaft-governor" is attributed to J. C. Hoadley; but the Buckeye engine, employing a design of shaft-governor in connection with balanced or relieved flat valves, commanded a commercial success which has made it a representative type.

A piston speed of over 1,000 feet a minute has been employed in large sizes of both of the positive cut-off engines mentioned. Large Corliss engines are rated to be run as high as 720 feet a minute. Usual speeds are less even for positive cut-offs. H. A. Hill gives as the present status of good high-speed usage 300 to 200 revolutions for engines of 50 horse-power and under, 160 to 125 revolutions for 50 to 150 horse-power engines with 20- to 30 inch strokes, and 120 to 90 revolutions for 200 to 800 horse-power engines with 30- to 48-inch strokes.

In 1869 the Novelty Iron-Works, of New York, commenced the manufacture of a new slide-valve engine with the Horatio Allen style of bed (Fig. 14). These were made in standard sizes from 5 to 350 horse-power in two

series, with long and short strokes and various ranges of speed. The short strokes were less than two diameters of cylinder and the long strokes over two diameters. The speeds of engines from 25 to 50 horse-power were rated at from 131 to 45 revolutions per minute for the long and 212 to 78 revolutions for the short strokes. The speeds of engines from 60 to 150 horse-power were rated at from 104 to 40 revolutions for long (24- to 48-inch) strokes and 168 to 63 for short (15- to 30-inch) stroke. The speeds of engines from 175 to 350 horse-power were rated at from 87 to 33 revolutions for long (36- to 60-inch) strokes and 42 to 142 for short (21- to 48-inch) strokes.

The latest development is in the usage of what are known as single-valve automatics. These govern by aid of variable compression acting jointly with variable admission. This principle was first dwelt upon by Mr. Harris Tabor. The compression goes far to reduce loss by clearance and internal condensation. As a measure of economy "there is nothing so promising which comes with so little cost". (Tabor.) The single-valve automatics are not so much designed to produce absolutely the most economical results as to get "the most for the money" with the best uniformity of speed. It is argued that it is "the attempt to save the last per cent. of fuel" which involves a cost overbalancing the slight advantage gained.

The Richards indicator was introduced in 1867 as a practical device for determining the power of engines speeded so high as to render worthless the indications of instruments previously used. The requirements of high speeds have now so advanced that the Richards is held suitable only for the indication of low-speed engines, numerous devices, such as those of Thompson, Brown (Crosby), and Tabor, having been invented for the indication of powers under higher speed.

The following tables make an exhibit of the range of speed as practiced in various kinds of work. They are gleaned from data furnished by the Buckeye Engine company, Salem, Ohio, of the usage of their engines. There is first a table showing fastest, slowest, and average number of revolutions per minute for various classes of work, the corresponding power or average power being cited as developed in each case. This conveys a good idea of the average size of engines to which the speed bears reference. The usual rated power is as developed with a mean effective pressure of 35 pounds from an initial pressure of 80 pounds cut-off at about one-fifth of the stroke. Of course different classes of work embody different conditions and different engine powers, in the light of which the figures have to be interpreted. A second table shows, in a similar manner, the ranges of piston speed in various classes of service:

TABLE I.

Kind of service.	Revolutions. Fastest. Revolutions.	Fastest. Power.	Average. Revolutions.	Average. Power.	Slowest. Revolutions.	Slowest. Power.
Cotton and woolen mills	215	20	159	133	100	600
Electric lights	215	150	159	65	100	150
Stove works	200	25	151	46	100	100
Machine-shops	225	30	142	62	75	40
Paper mills	215	30	137	96	85	125
Malleable iron works	150	60	132	59	100	50
Flouring-mills	225	25	129	80	85	150
Iron works (rolling, etc.)	150	200	129	93	100	80
Print works	160	1,000	127	714	102	250
Wood-working	160	80	120	89	70	150
Mining	175	70	104	178	83	350
Wire-mills	100	175	100	157	100	140
Silk mills	110	80	95	80	80	80
Grain elevators	96	200	92	422	80	90
Brass works	120	55	91	72	75	60

TABLE II.

Kind of service.	Speed in feet per minute. Fastest. Feet per minute.	Fastest. Power.	Average. Feet per minute.	Average. Power.	Slowest. Feet per minute.	Slowest. Power.
Print works	960	1,200	788	714	500	120
Mining	800	400	577	178	350	50
Wire-mills	600	175	566	157	533	140
Grain elevators	760	1,200	536	422	426	90
Paper mills	800	125	527	96	466	30
Cotton and woolen mills	626	600	506	133	450	40
Electric lights	626	80	506	65	450	40
Flouring-mills	600	200	493	80	400	60
Silk mills	600	150	485	128	346	80
Malleable iron works	540	80	471	375	375	30
Wood-working	600	75	466	89	373	75
Iron works (rolling, etc.)	584	70	463	93	350	40
Machine-shops	666	200	461	62	250	40
Stove works	500	100	441	46	350	30
Brass works	480	55	418	72	350	60

A graphic exhibit of the effect of speed and automatic cut-off upon the size of engine is shown in a diagram comparing four sizes of engines of nearly the same power between 100- and 125-horse power.

A and B represent the cylinder sizes of automatic engines with steam at 80 pounds initial, cut-off at one-fourth stroke. A is speeded at 78 revolutions and is a drop cut-off. B is speeded at 150 revolutions and is a positive cut-off.

C and D represent the cylinder sizes of throttling or plain slide-valve engines. C is speeded at 70 revolutions, D at 600 revolutions (as tested by the speed-indicator).

All of these are practical serviceable engines in competition on the market to supply like powers, although not equally suitable for different purposes. D represents a direct-attachment saw-mill engine, of the durability of which, despite its small proportions, we have had some evidence. As compared with B, an example of a high-

speed automatic for electric lighting, it is seen to be far in advance in point of speed, although antedating the high-speed automatic. Comparing A and C, it is plain that steam is so throttled and wasted by C that A, with steam cut-off at one-fourth of its stroke, develops equal power, though a smaller bore of cylinder. A is also higher speeded, and shows the advance in speed made by the drop cut-off automatics over the early types of throttling-engines.

With D the economy is very much better than with C, for the steam is used quick and hot, the best regulation of speed is attainable and throttling becomes less injurious to efficiency. The piston speed of A is 556, of B 600, of C 420, and of D 1,200 feet a minute. With the same mean effective pressure per square inch the pressure coming on the crank-pin would be in the proportion of about 6,000 for A, 5,000 for B, 11,000 for C, and only 2,500 for D. In fact, C uses steam so much throttled that the mean effective pressure is less, and the average pressure upon its crank-pin would be about 8,000 pounds.

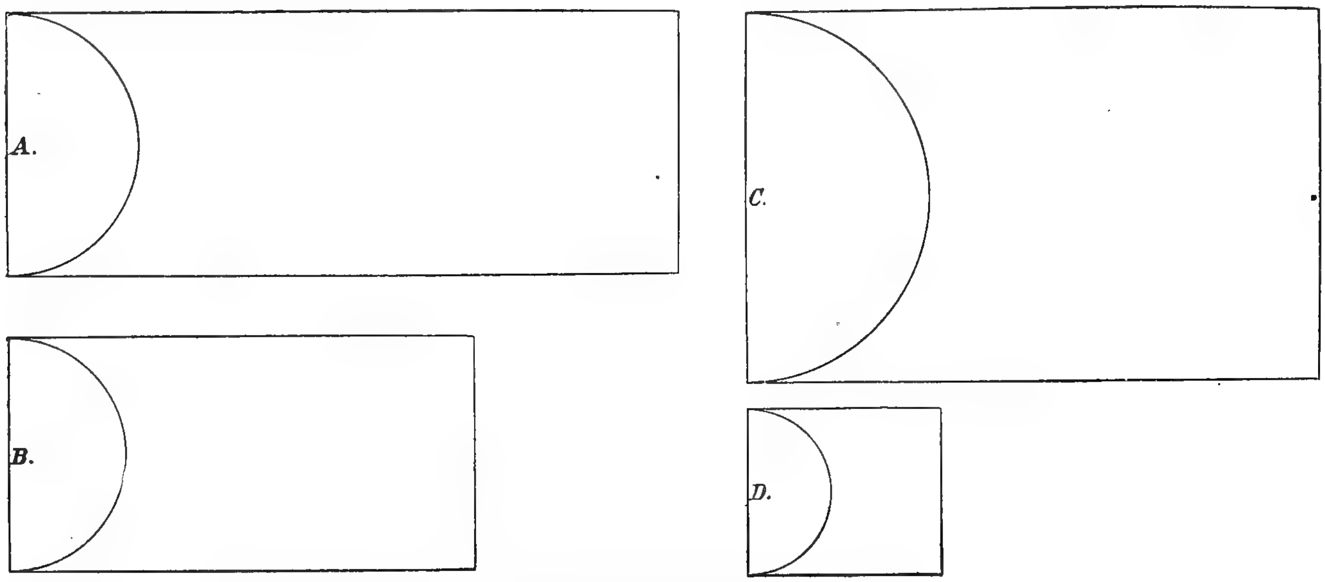


Fig. 12.—Comparison of Engines of Like Power.

Mention has been made of the use of belts, instead of gears, as an American improvement, but a still greater innovation is in progress. For low speeds a pulley fly-wheel with belt is used, but for high speeds of engine, belts are discarded, and by means of a coupling and balance-wheel direct connection is made to the end of the line-shaft. Both positive and drop cut-off engines are used in this way. The practice is mainly employed in rolling- and in flouring-mills, but the tendency is to make it more general for other classes of work. A notable example of the employment of this practice in shops is afforded by Colt's armory, Hartford, Connecticut, in which the principal power is furnished by four Porter-Allen engines coupled to the main shaft. As this is one of the most notable instances of direct connection employed in a large machine-shop, an illustration is presented of two of these engines, which conveys a very good idea of the valve-gearing, and of the general arrangement for this class of service. One sectional elevation is shown, the section being through the center of the cylinder. There is also shown a side elevation, taken so as to exhibit the governor and its connection with the link-motion. The cylinders are beneath the level of a platform of the factory floor, which permits the use of a good length of connecting-rod, and the location of the crank-shaft near the ceiling at the usual height of mill shafting. The shaft makes 130 revolutions per minute. The cylinders are $12\frac{1}{2}$ inches in diameter by 24 inches stroke, and are rated at 75 horse-power each, or 300 horse-power for the four. The engines were built in 1867 from the designs of Mr. Charles B. Richards.

The first Porter-Allen engines which were applied to rolling-mill service were put in the Albany and Rensselaer Steel works on the recommendation of Mr. A. L. Holley. This was in 1876 or 1877. The engines had 18 by 20 and 22 by 36-inch cylinders; and in 1880 a 22 by 36-inch engine was put in to drive a rod-train, and this was driven at 200 revolutions per minute, or the great piston speed of 1,200 feet a minute, the piston going a mile in less than $4\frac{1}{2}$ minutes. The operation of these high-speed engines has been very satisfactory.

There are examples of Corliss engines coupled to line-shafts at from 50 to 110 revolutions, principally in the flouring-mills of the west. With the high-speed engines, from 100 to over 200 revolutions per minute are usual for this class of service, and it is stated that, owing to the reduced weight of engines, fly-wheels, and framing, the cost is sometimes reduced as much as one-half from the cost of belted engines of the same power. This is a characteristic American practice, and it is justly regarded as a great advance in economy.

Among the various types of automatic cut-off engines, competition has been so active that there is not one of the leading designs which has not been perfected so as to exhibit a high degree of economy, and the matter of selection is often reduced to a question of wear and workmanship rather than to the exhibits of close results in competitive trials, whose conditions may not be maintained in practice.

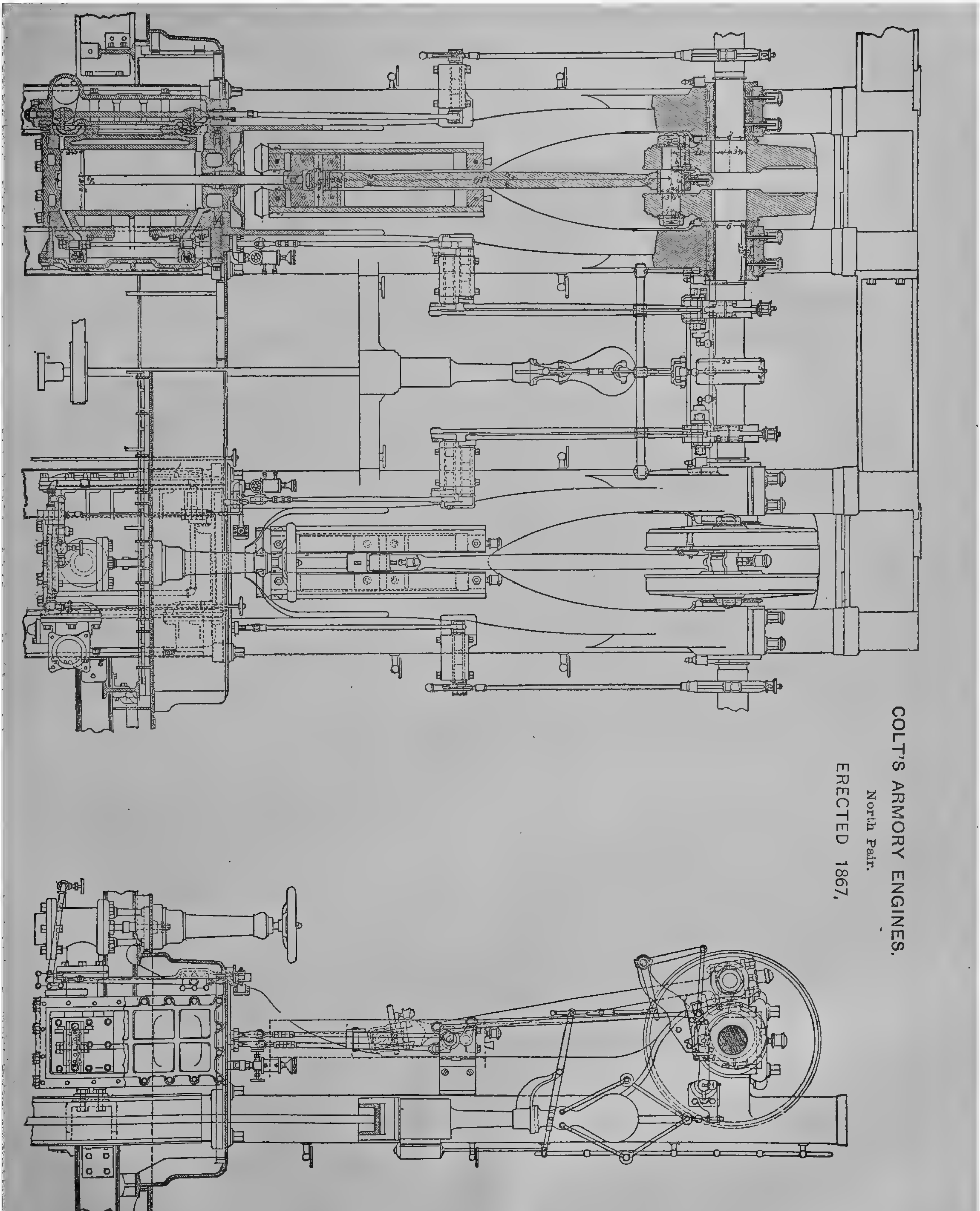


FIG. 13.—COLT'S ARMORY ENGINES.

Into the conflict of trade opinions we cannot enter. The nature of service will often determine the selection of a proper speed. "As between the standard automatic engines of to-day, the inherent differences as to economy are so small as to belong rather to expert investigation than to practical account." It is truly said that the causes of fuel waste are more often to be found in the conditions under which the engine is compelled to work than in the engine itself.

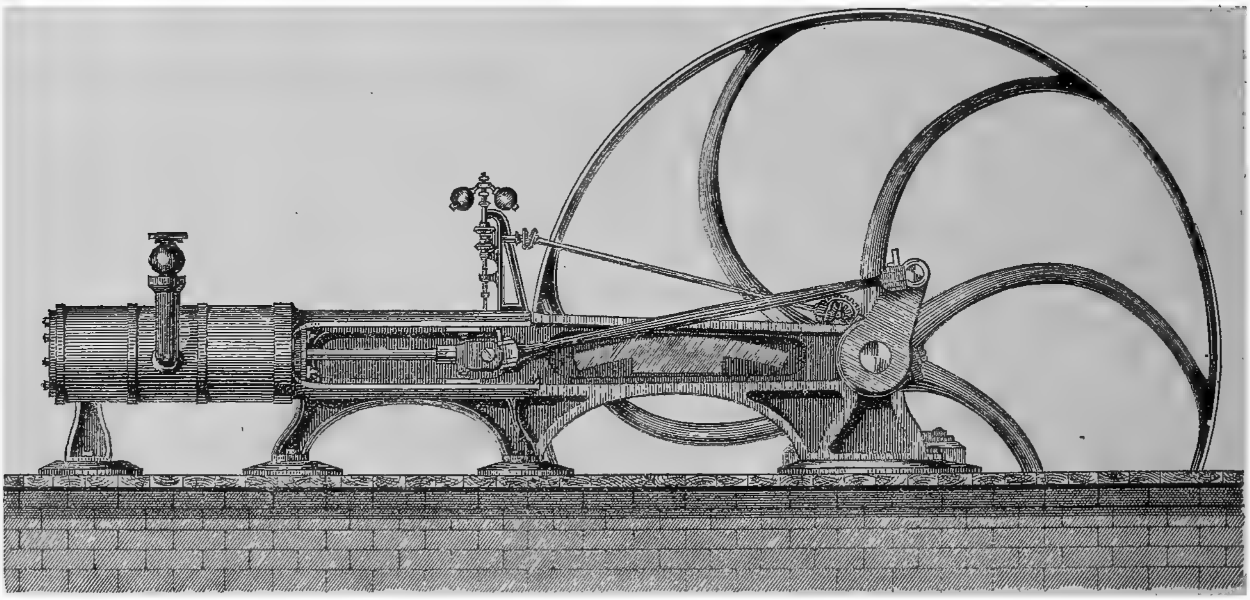


FIG. 14.—NOVELTY IRON WORKS ENGINE.

TYPES OF STATIONARY ENGINES.

Valve-gears.—"The description of an engine naturally commences with the valve-gear and the valves" (Porter), for these are the most distinctive features of an engine.

Nearly all engines employ an eccentric, secured upon the main shaft either flexibly or rigidly, as may be determined by the requirements of the valve-gearing. The eccentric is a well-approved feature. It furnishes large bearing surfaces with small stress, and generally gives little trouble, although it is sometimes caused to heat by the attempt to drive valves of heavy resistance at too high a speed. The action of the eccentric is precisely similar to that of a crank with a radius equal to the eccentricity, and its motion is usually communicated to the valve by means of a strap and rod.

In foreign practice a return crank is often used instead of an eccentric, more rarely here, although the Warren engine (Fig. 17) shows this usage. It brings the steam-chest on the front of the cylinder and permits unlimited length for the main bearing.

It is sometimes desirable to use small eccentrics which cannot be placed upon a large shaft, and an auxiliary shaft is used geared from the main shaft. The object of this is to lighten the valve-gearing and to effect certain motions of closure with a short quick throw. Such auxiliary eccentric shafts are used on some types of Corliss engine and on the type of Cummer automatic engine shown in Fig. 26.

The bearing joint between the eccentric and its strap is usually cylindrical and stepped, having proper grooves for lubrication. In the Buckeye engine the joint is made spherical, so as to be capable of easing and adjusting itself in any direction.

The eccentric is double-acting. Even in the Westinghouse engine, with its claims of single action avoiding the loosening of connections, the eccentric-rod is an exception. In a few cases cams are used in place of eccentrics, or "lay shafts," geared from the main shaft, carry cams, which operate the stems of valves of the poppet type.

In engines of the throttling- or plain slide-valve type the governing principle is not applied to the valve-gearing at all, variations in speed serving only to vary the opening of the throttle-valve in the steam-pipe. Figs. 14, 15, 16, and 17 are illustrations of this type of engine.

A variable cut-off engine is one in which the valve-gearing may be adjusted by hand while the engine is running. The adjustment may be applied to the valves as in Meyer's gear, in which riding cut-off valves moving upon the face of a main valve are changed in position by a right-and-left screw varying the cut-off. In Rider's gear the valve is cylindrical, with admission edges at such an angle that the cut-off is varied by turning the axis of the valve. A like effect may be obtained with flat valves and inclined port-openings, as is done in the Watertown engine, in which it is used automatically; that is, the cut-off is determined by the position of weights in a governor. Rider's and Meyer's gears are also employed automatically.

Hand adjustment is applied to connecting links between the eccentric and the valves in many cases, notably in locomotive practice, where it is universal; and in traction, hoisting, and other engines, which may be speeded up

to their load with little or no dependence upon centrifugal governors. Hand adjustment may be also applied in varying the cut-off by shifting the eccentric or by altering the throw of the valve through the operation of cams, gears, and levers, as in various devices, some of which are used upon traction engines. In some large compound Corliss engines, the cut-off is made automatic on the high-pressure cylinder with the usual releasing gear, while on the low-pressure cylinder the cut-off is merely set at a given point, which may be readily varied by hand adjustment. In such a usage the bit may be said to be in the mouth of the leading cylinder only, which suffices for the automatic government of the speed of the entire engine.

Automatic valve-gears may be defined as of two types, releasing and positive. These are characterized by several important differences, upon the merits of which there is much discussion. The gears in both types are positive for the main movements of the valve or valves governing the admission and exhaust of steam. The lead, that is, the movement of the valve from its position corresponding to that with the crank on its center to its position when it begins to uncover the steam-port, is usually unchanged. In Corliss engines and in positive cut-off engines with set eccentrics moving a main valve it is unchanged. In an engine such as the Armington and Sims

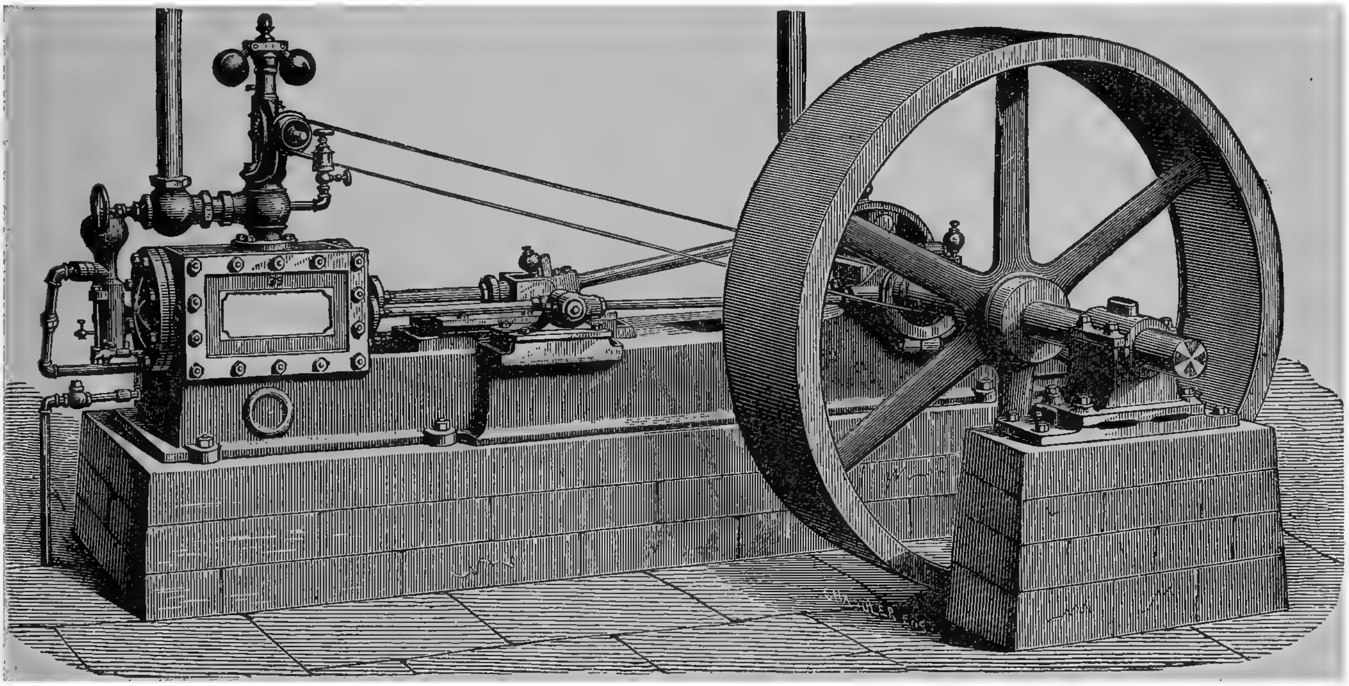


FIG. 15.—ATLAS SLIDE-VALVE ENGINE.

(Fig. 23) the same effect is secured in a combination of two eccentrics, one encircling the other. The lead in all positions of the eccentrics remains constant and practically unchanged. In the Straight Line engine, with what may be called a position eccentric-rod projecting upwards at a slightly variable angle (Fig. 25) from the center line of the engine, the connections are such as to maintain a practically constant lead for all points of cut off from $\frac{3}{4}$ to 0; this with a single valve and eccentric. In the Porter-Allen engine the tipping motion of the curved link properly adjusted imparts a slight difference of lead at the ends of a cylinder, corresponding nearly with the difference of motion of the piston, due to the angular vibration of the connecting-rod. The Porter-Allen engine either uses a separate eccentric (Fig. 13) for its exhaust-valve or operates both valves with one eccentric, as in the engine shown in Fig. 24.

In the positive cut-off engines governing mechanism is applied to shorten or lengthen the throw of the cut-off valves, or to alter their distance apart for the same throw. It is applied in moving a block in a rocking-link in the link-motion engines, and in moving an eccentric in respect to the center of a shaft from which it derives its rotary motion, as is usual in the "shaft-governor" engines. In either case the outcome may be well expressed by using the sailor's term, and saying that we take a reef in the valve travel. The governor is said to be "saddled with actuation," that is, it must vary the cut-off and move the valve-gear under stress. This involves power in the governor, and the power must be derived from the centrifugal force of heavy weights driven in rapid rotation by the engine itself.

But little work is involved in driving these governors. In the shaft-governors the weights operate as so much fly-wheel weight, which long-stroke releasing-gear engines would require in larger proportion. In "actuating" governors the inertia which is acquired conformably with the speed of the engine has only to be changed from time to time by very small increments, so that there is no hesitancy in effecting any change of cut-off that may be required. In the Buckeye governor all the joints are spherical, and kept continuously, though slightly, working by the rapid succession of small resistances. The action of such a governor may be compared with that of a large ball in motion rolling over small inequalities upon the ground. The resistances are there, but they seem overcome with scarcely appreciable effort.

In point of sensitiveness, any effort required by actuation is probably more than compensated by the more frequent opportunities for cut-off afforded by short-stroke engines, and the great power of governors, such as those of the Straight-Line engine and the Ball engine (Fig. 27), is obtainable at no more first or running cost than that of so much fly-wheel.

In the releasing-gear engines the governing mechanism is applied merely to locate a tripping toe or block, the stress upon which is slight, and in some of the latest improvements in engines of the Corliss type may be said to amount to nothing. It has practically no work to do, and is free to respond with the greatest delicacy to slight pulsations of speed. The movement required for disengagement is slight; but it is sufficient. Hard steel blocks and catches are employed, by which great accuracy and durability are obtainable in these light working parts.

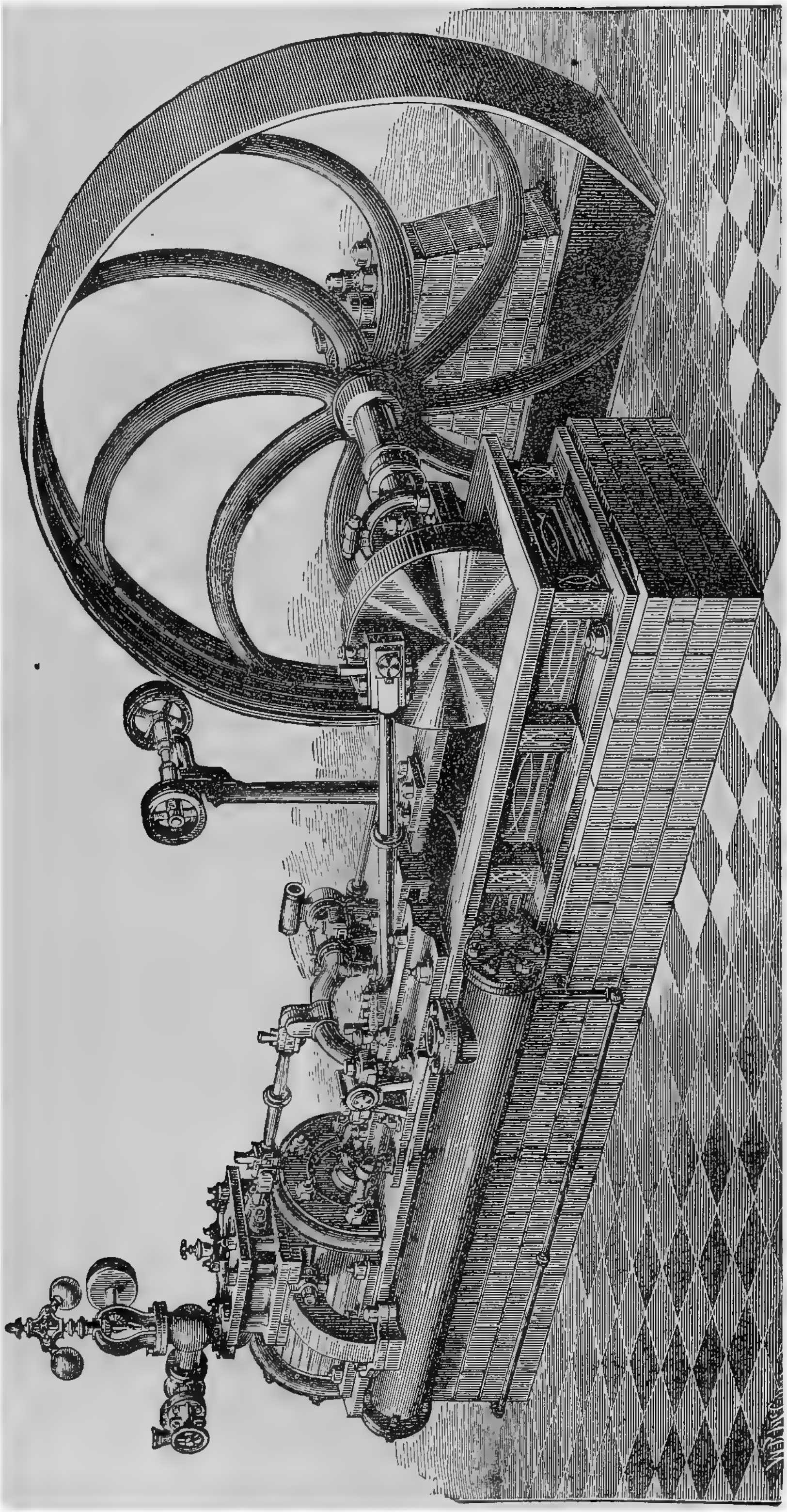


Fig. 16.—Cincinnati Slide-Valve Engine.

The Corliss principle of release may be applied to flat gridiron- and poppet-valves as well as to the usual taper or cylindrical valves. The details of mechanism employed by builders in this country and abroad are too varied for full consideration here, and we shall confine ourselves to a description of some of the salient features of leading types.

Motion is communicated from the eccentric through rocker-arms (required to sustain the necessary length of eccentric-rod) to a rocking wrist-plate, from which small connecting-rods communicate motion to four (sometimes in case of compound engines to eight) rocking valves. The exhaust-valves have positive connections, as do also the steam-valves for their admission and up to the point of cut-off. Then a toe, usually upon a bushing concentric with the hub of the admission-valve rock-arm, disengages the connection with the wrist-plate. Another arm connects the valve-stem with a rod leading to the piston of a vacuum or spring dash-pot. This has been drawn up by the previous motion, creating a vacuum. The piston now returns to fill this vacuum, rocking the valve backward and effecting a prompt cut-off, as Corliss engine diagrams will generally show. Upon the return movement of the wrist-plate a small spring causes the connecting-rod to the admission-valve rock-arm to re-engage positively, ready for the admission of steam.

George H. Corliss has himself devised numerous modifications of his invention, of which the mammoth engine for the centennial exposition at Philadelphia is a design familiar to many. Of the earlier designs for stationary and factory purposes a well-known arrangement employed a wrist-plate rocking a heavy spring-arm forward of the cylinder. A light curved spring wrapping upon the back of this arm assisted the vacuum-pots in cutting off steam as soon as the point of release was determined by the governor. The type of Corliss gear now in most common use in this country embodies an arrangement substantially of his device, but more favored in practice by others than by himself. This

has a wrist-plate in the middle of the cylinder, as shown in Figs. 18, 20, and 31, the engines of other builders. In Fig. 18 the so-called crab-claw of the releasing gear is placed on the end of the connection from the wrist-plate. In Fig. 31, showing a design by Edwin Reynolds, the "crab-claw" depends from an extension of the rocker-arm above the valve-stem.

In the Atlas-Corliss engine the employment of an auxiliary shaft with two eccentrics permits a steam-admission cut-off beyond mid-stroke, at which the range of admission of releasing-gear cut-offs with single eccentrics is limited. In the Wright engine the admission-valves are gridiron slides, but the principle of release is the same.

An "indicating" cut-off gear of an entirely different type is shown in Fig. 32, which illustrates a heavy rolling-mill engine built by E. P. Allis & Co., of Milwaukee, Wisconsin. Its action is thus described by Mr. Hoppin:

> The raising or lowering of the governor-balls moves small valves, which admit water under pressure into one end of a small cylinder and exhaust it from the other end. There is in the cylinder a piston, connected by a rod to the valve mechanism in such manner that the movement of the piston advances or retards the time of closing of the cut-off valves. The cylinder is at all times full of water, and when the engine is at its correct speed the governing valves are all closed, thus locking the piston in position. Any movement of the governor allows water to enter at one end of the cylinder and to escape at the opposite end.

This device is essentially different from the Corliss in that there is no disengagement, and different from most forms of positive cut-off in that the governor does not do the work of shifting the cut off. The valve motion is positive, the connection is unbroken, but water-pressure is called in to do the work.

The method of securing the eccentric is determined by the character of the valve-gear. In throttling-engines, in Corliss automatics and link-motion automatics, and in the main eccentrics of double-eccentric shaft-governor

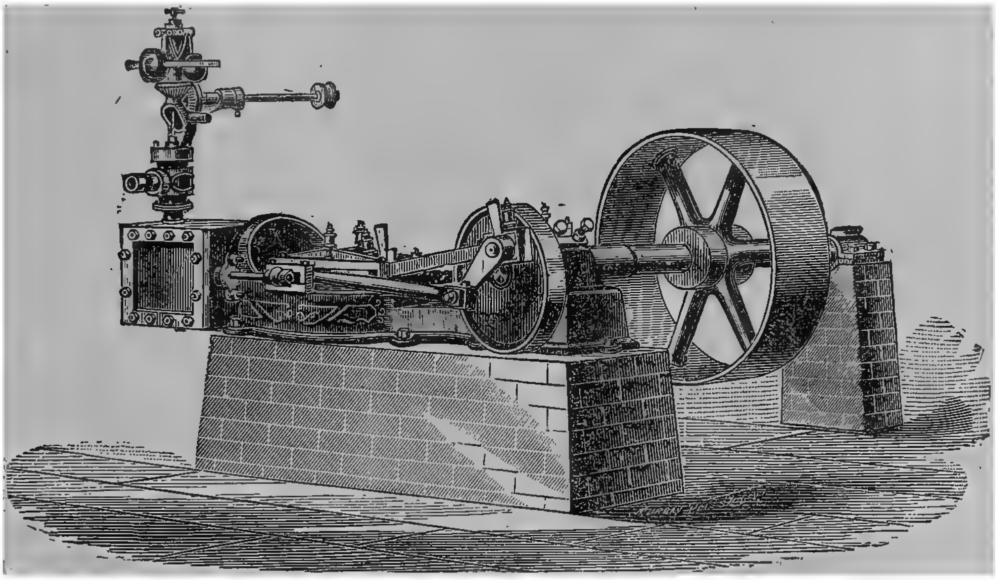


FIG. 17.—WARREN (OHIO) HIGH SPEED ENGINE FOR DIRECT CONNECTED SAW-MILLS.

engines, it is made fast to the shaft sometimes by a key, more often by set-screws. The Porter-Allen engine has its eccentric in one piece with the shaft and in the same position as the crank, instead of at right angles to it, as usual. The link is of the Fink type, formed in one piece with the strap, and capable of movement upon rocking trunnions. The main eccentric of the Buckeye engine is secured to the shaft by a wedge-bolt and toothed block, permitting of ready adjustment.

The loose eccentrics of shaft-governors are most commonly pivoted upon a pulley or disc secured to the shaft. These eccentrics are formed with an elongated eye, through which the shaft passes, permitting a play which furnishes the desired range of cut-off. The throw of the eccentric is so designed that the lead is only slightly changed in the whole range of cut-off, and in some cases causes the valve motion to be "timed with the piston motion, giving a quicker admission for the port at the head end than for that at the crank end of the cylinder." (Joshua Rose on the Ide Engine.) An eccentric merely turned upon its shaft, as is the case with the Buckeye cut-off eccentric, would vary the lead, but with the Buckeye the lead is governed by the main eccentric, and the rocker of the cut-off eccentric-rod is so mounted on the main rocker as to produce a combined cut-off movement, securing quick closure and a travel favorable to uniform wear. The Armington and Sims engine also has an eccentric turning upon its shaft, but here the encircling eccentric compensates in such a way as to preserve uniformity of lead. The devices employed in shaft-governors are very numerous. Instead of the swinging motion upon a pivot some designers employ compound slides, Watt or other parallel motions or traversing-gears, to move the eccentric straight across the shaft, as may be determined by the revolving weights with their controlling springs, which constitute the governor.

Governors.—Of the governors employed in regulating throttling-engines the Judson was a type at one time almost universally used upon small and medium-sized engines. In this a pulley drives a pair of bevel-gears in

the yoke of a frame, operating a sleeve-spindle, in an enlargement of which the arms of balls are pivoted. The balls, being thrown outward and upward by revolution, depress a central rod by means of sockets in which the ends of the ball-arms work, and thus close a valve. In the Pickering governor the balls are held by slightly curved springs, and there are no joints. In the Waters governor—a very popular type—the balls are fastened upon curved springs. The Gardiner governor is much used, and the Tabor governor, recently introduced, is more complex in construction, but makes claim to great nicety of regulation. Upon the details of these small governors we will not dwell. They have been perfected by much study and experiment until results have been reached which place the throttling-engine on a much better footing as compared with automatics than it could have held a few years ago. A small engine running under a constant brake load with one of these governors did not vary speed 2 per cent. in a fall of boiler pressure from 100 to 50 pounds. Under 100 pounds steady boiler pressure the load on the brake was increased from 10 to 50 pounds without causing the variation of a revolution, to 100 pounds with a variation of speed of less than 1½ per cent., and to over 300 pounds with a variation of 5 per cent.

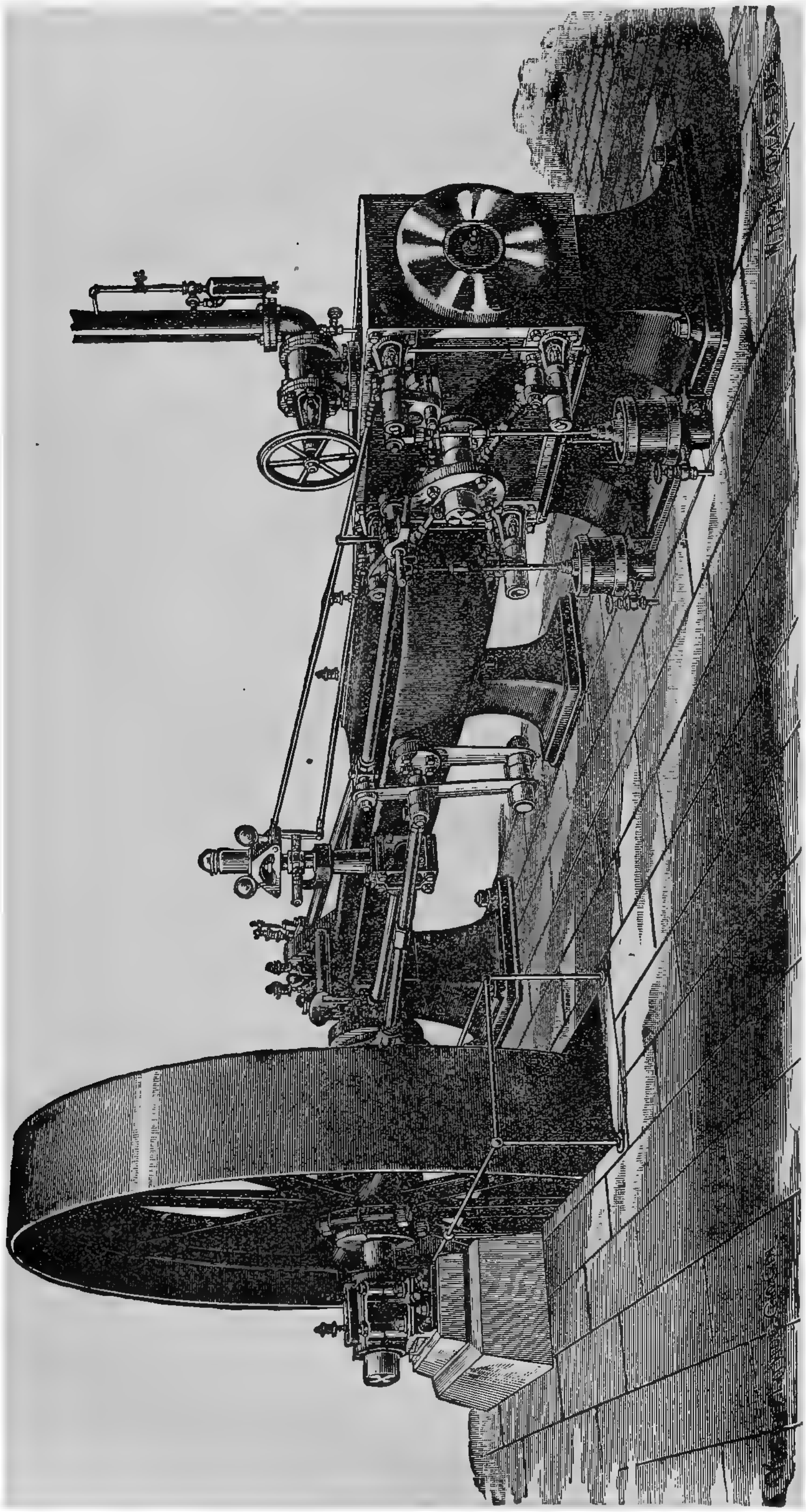


FIG. 18.—CORLISS ENGINE, WITH CAST-IRON FRAME (CINCINNATI, OHIO)

Upon large engines the Watt type of revolving pendulum governor is commonly used, being often modified by springs or dash-pots to increase sensitiveness and prevent vibrations. The Porter governor, in which the sensitiveness of regulation is increased by a weight encircling the spindle and not subject to centrifugal action, is very much employed.

In recent years the chief development has been in the introduction of shaft-governors, which have given character to many new types of automatic engines. The weights are commonly hinged upon the arms of pulleys or upon discs secured to the shaft. They revolve in a vertical plane, with a tendency to fly out by centrifugal force which is restrained in part by powerful springs. These are in most cases of spiral form, and subject in some designs to extension, and in others to compression. The forces of weights and springs are unbalanced to an extent necessary to overcome the friction of the valve mechanism, the preponderance being sometimes as much as 10 per cent. in favor of the weights, although it may be made in favor of the springs. The springs are commonly attached to the same hinged-arms to which the weights are secured, and in many designs the initial tension of the springs and their points of attachment may be adjusted to secure the best results. The weights may also be moved so as to alter their leverage and their power relative to the resistance of the spring. With these arrangements it is feasible to secure substantially isochronal government, although this is by no means obtained in many designs. Many of the springs used do not give like increase of stress for different equal increments of extension, and the leverages

commonly vary for the different positions of the weights. It is feasible to make these variations tie with the variation in the resistance of the cut-off valves for different points of cut-off, and also to cause the engine to speed up under a heavier load.

The methods of conveying motion from the weight-levers to the eccentrics are various. Links are commonly employed attaching to ears upon the eccentric or upon a disk or wing-piece which so gears with the eccentric as to cause its movement around (relatively to the position of the crank) or across the shaft. In one design (Giddings') compound slides are used, which insure a certain degree of stability against vibrations, without which, and with a close balance of weights and springs, there is a tendency to "race". In another design (Ide's) a small dash-pot filled with glycerine secures freedom from these oscillations without sensible impairment of sensitiveness. The use of the dash-pot is to cushion shock and distribute vibration, as oil smooths the surface of troubled water. It is sometimes criticised, but from a purely mechanical standpoint its use is as legitimate as that of a fly-wheel. In another design (Bogert's) the system of weight-connections is made to constitute a Watt parallel motion, the system being balanced by a single spiral spring. In still another (Bigelow's) the flying weights have toe extensions, which operate against the resistance of springs a sliding block to which the eccentric is secured. The block is made to slide upon round rods, and balance is maintained by three springs in equilibrium. In the well-known design of Professor Sweet in the Straight-Line engine a single weight is used, balanced by a powerful spring, which is slightly curved and formed of flatted leaves like an elliptic car-spring. This makes a powerful governor, and is probably the simplest of all, the eccentric being of the pivoted type, and swung across the shaft by an ear attaching to a point of a link which connects the end of the curved spring with the end of the weight-lever.

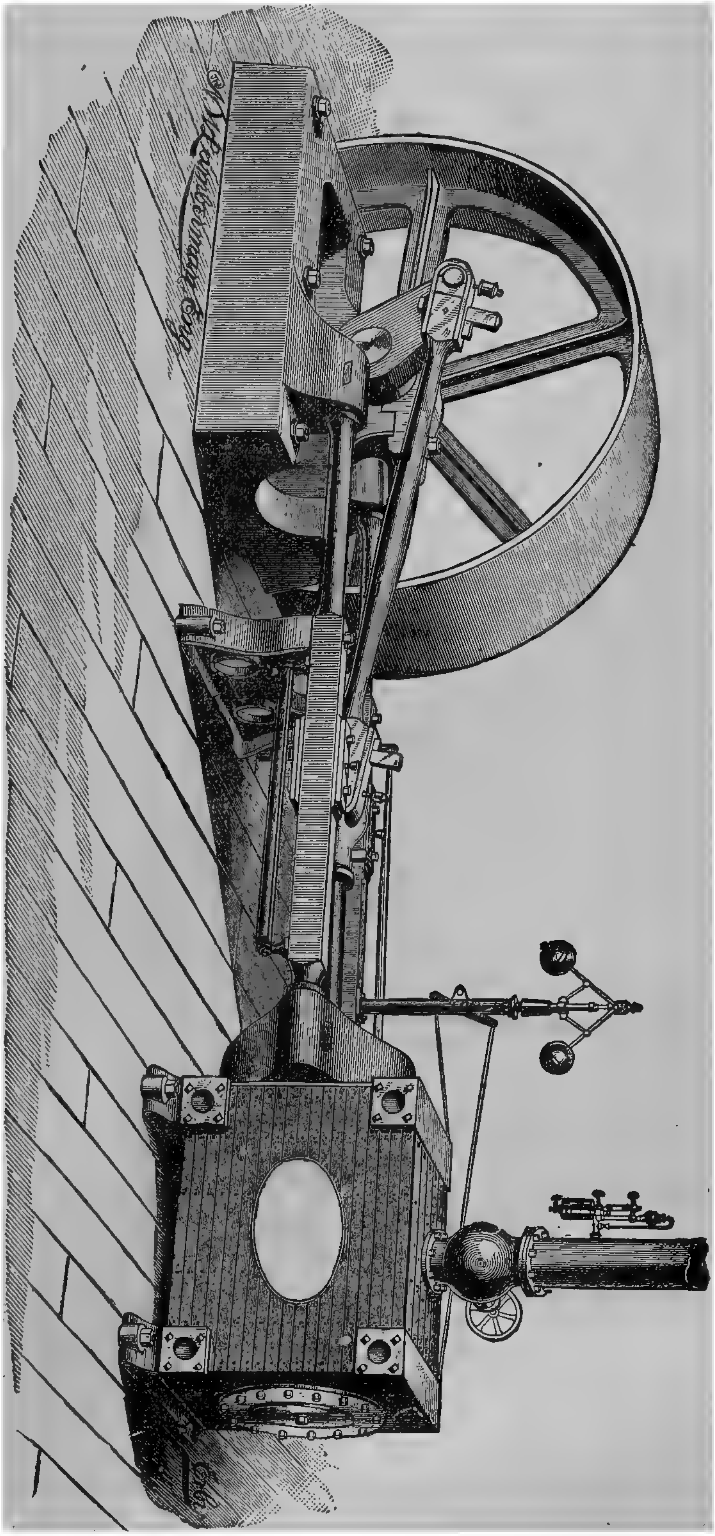


FIG. 19.—CORLISS ENGINE, WITH WROUGHT-IRON FRAME (MILWAUKEE, WISCONSIN).

There is scarcely a mechanical movement which is not capable of application in the arrangements of a shaft-governor, and the efforts of inventors seem to be becoming more and more prolific, and will not be followed at great length. Mr. F. H. Ball is the inventor of a governor in which a new principle of regulation is claimed. A pivoted eccentric is used with the pendulum motion across the shaft, obtained by the movement of a disk which has an internal eccentric ring engaging with a stud in the eccentric. The disk is moved by connection with weights hinged upon the arms of a pulley and balanced by spiral springs secured to the same pulley as is usual. But the pulley is not, as usual, keyed to the shaft, but is mounted free to revolve upon a hub keyed to the shaft with wings or arms connected by springs to the weight-arms pivoted upon the pulley. The pivotal stud on which the eccentric swings is also placed upon one of these wings. The power of the engine is exerted through the shaft, hub, wings, and spring connections, and weight-arms to the pulley upon which runs the driving-belt. The load is the tension upon this belt, and any variation in it acts upon the governing system of weights and springs before the changed resistance taxes or relieves the power which is being exerted by the engine at the previous point of cut-off.

The power depends upon the regulation of steam supply, and if this depends, as usual, upon variation in speed our premise precludes the possibility of reaching uniformity of speed. This it does not appear to do *in terms* if our steam supply is made to depend upon variation in load, but, in fact, as speed and load are related, variation in load *is* variation in speed so far as the driven mechanism is concerned. Fly-wheels in the power train near the driven mechanism cushion pulsation and secure smoothness of running as well as those upon the engine-shaft. Ordinarily the pulsation due to change of load is gradually taken up by the fly-wheel and gradually felt by the engine in speed and in adjustment of steam supply to meet load with power and restore the former speed by a new equation. In the Ball engine the first draft upon the engine by increased load changes the provision for steam supply *before* the engine speed is retarded in compliance with the unalterable laws of inertia. The action is prompt, the governor may be said to weigh the load, and the practical outcome is a guarantee of less than a revolution variation in speed between an engine running loaded and empty.

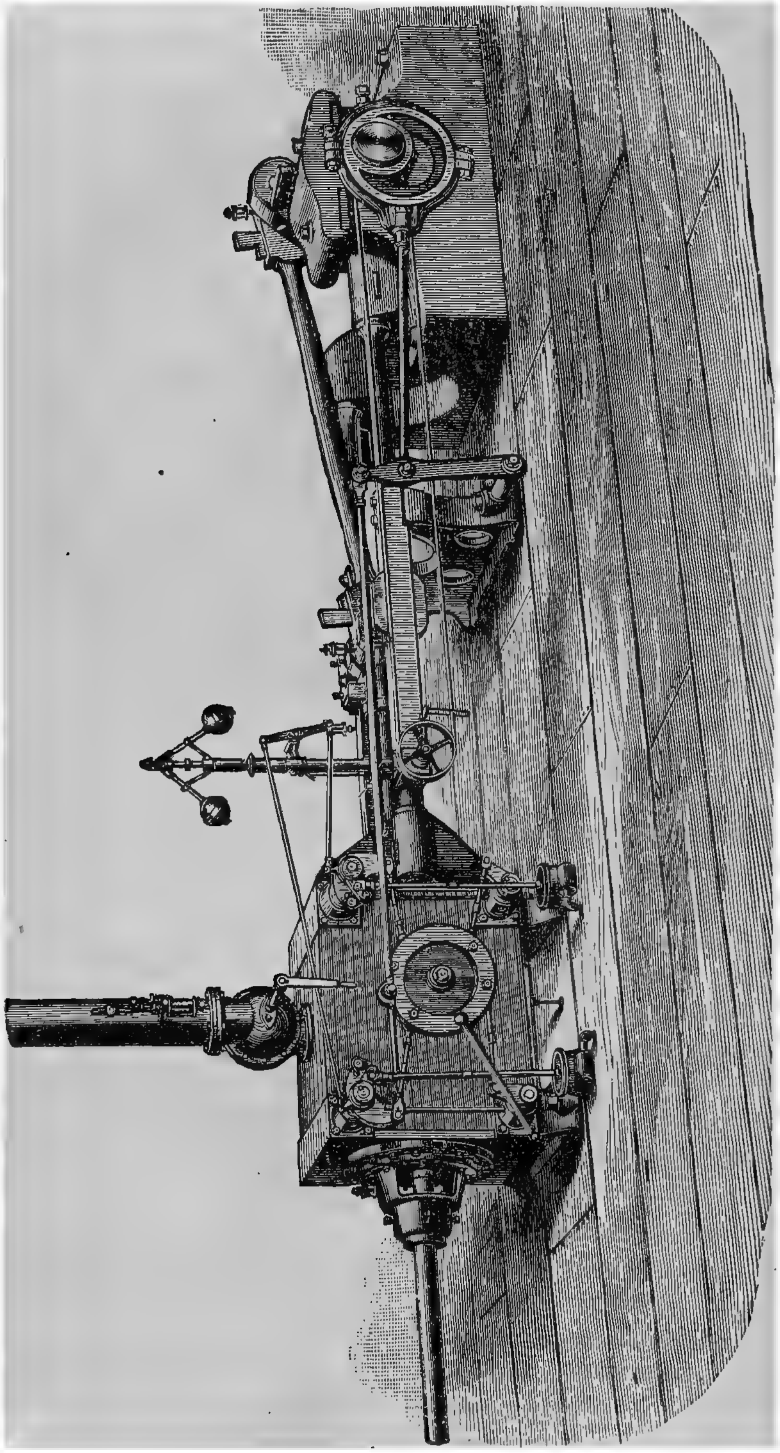


Fig. 20.—Corliss Engine, with Extension-Rod.

But the advantage gained is slight in fact. It is only an advantage in time in a transmission of power which is almost instantaneous. With the Ball engine increased load must do the work of slightly extending the connecting springs, and then the added load, with all its retarding effects, is upon the engine, unless the lost motion gained in the adjusting springs happens at the right instant to extend the impulse of full steam for the stroke of the engine that is taking place, and unless the inertia of the reciprocating parts is overcome before the pulsation of speed reaches the shaft. We have not come to such a refinement as shall smooth the variation of effort during a stroke except in the matter of regulating the inertia of the reciprocating parts, but the advantage of the Ball system of regulation seems to fall within the limits of these variations.

The chief object of a smooth-running engine is to obtain smooth-running machinery. This is done as far as practicable in the best types of automatic engines of various designs. Where shocks and sudden variations arise from the operation of the driven mechanism fly-wheels may absorb these shocks, but the closest obtainable government of engines can not prevent them.

The Cummer governor exhibits the application in shaft-governors of a principle similar to that of the Porter governor among revolving pendulum governors. The sensitiveness is increased by a dead weight acting in conjunction with lighter weights, which only are subject to centrifugal force. The Cummer may thus be said to occupy the position in respect to other shaft-governors which the Porter occupies in respect to the Watt governor. This feature involves some peculiarities of construction, which require an auxiliary eccentric shaft, especially in cases of a coupled or extended main shaft. The revolving weights have links attaching to bell-cranks, by which they are connected to a rod in the hollow center of the shaft. The rod extending out from the end of the shaft connects with a bell-crank rocker, on one arm of which hangs the dead weight, as shown in Fig. 26. A spring also attaches to this arm, and it affords a ready means of adjustment for speed. An engine of this type fully loaded

in driving electric lights may have its entire load thrown off at once without any variation of speed that is perceptible to the observer. The best types of high-speed engine, such as the Armington and Sims, the Porter, the Buckeye, the Ball, the Straight Line, the Ide, and others (the variety in meritorious designs is constantly increasing), show similar close results in regulation. With correct adjustments any of these engines are capable of results sufficiently fine to meet any practical requirements even in electric lighting, and some of the most satisfactory plants for electric lighting, especially in the matter of fuel economy, employ large engines of the Corliss type. The employment of a large engine of any type (if the load requires a large engine) is more conducive to economy than the employment of small engines, but the convenience of having a small engine for each dynamo may outweigh considerations of fuel economy.

Valves.—The poppet-valve of the double-beat type has been described as a perfect valve in theory, opening a large area for a small movement and, if balanced, closing with a touch and without rubbing movement. They are sometimes employed upon stationary engines, but practically the conditions of high speed increase the difficulties of balancing, and cause a hammering upon the seats, which the use of dash-pots does not perfectly correct. They are therefore not a feature of any leading type of American stationary engine, and the three forms of valves whose employment is most common, and whose merits are most under discussion, are the flat slide, the piston-valve, and the rocking valve.

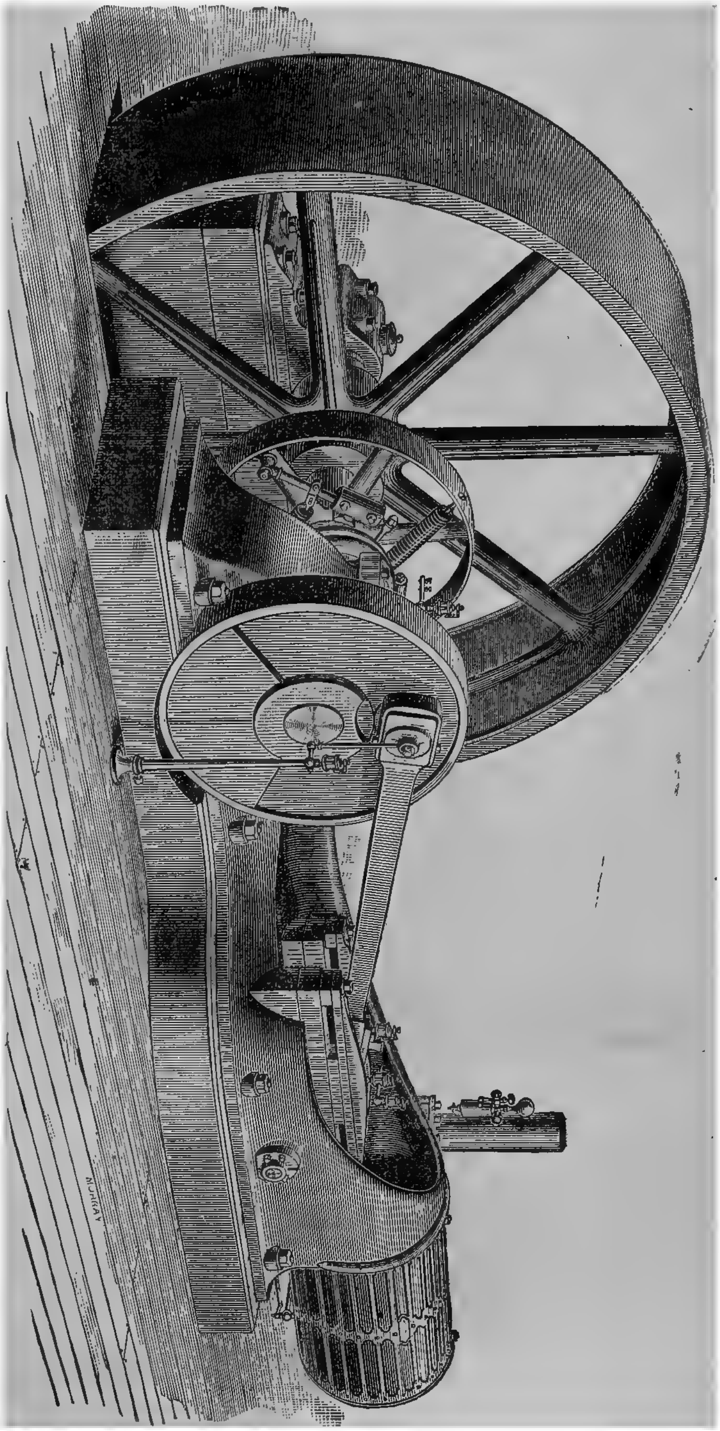


Fig. 21.—Buckeye Engine with Tangye or Porter Bed.

Whichever of these valves is employed designers have been alive to the importance of securing a large area of admission for a small movement. In sliding valves, whether flat or cylindrical, this end is reached by having two, or four, or more edges of admission. A flat valve, with several slots for multiple admission, is called a gridiron-valve. With piston-valves the number of admission-openings may be increased to any desired extent by using hollow valves slotted through, and working in bushings perforated in a similar manner. The rocking or Corliss valves have usually single admission edges, but the ports are wide and the valve travel is made quick at the point of opening. The arrangement for quick valve travel at certain acting points is a consideration belonging more truly to valve-gearing than to valves, but the quick wrist-motion obtainable in a proper design of Corliss valve-gear makes a single place of admission sufficient. The merit of this feature is recognized by Mr. Porter in the form of "Corliss wrist-motion", introduced into the connections of the admission-valves of the Porter-Allen engine, making a "differential valve movement", by which the opening of the valve is increased, and its lap may be reduced, permitting the use of narrower seats and smaller valves for the same steam-opening.

The wear of Corliss valves is slight, and is compensated in most designs by springs, which hold the acting portion of the valve to its seat. In some engines the valve-stem, instead of passing through the valve from end to end, terminates in a blade or T-head, fitting into a slot in the end of the valve. These rotary valve-stems are packed in various ways, sometimes by regular stuffing-boxes with glands, sometimes by ground joints without stuffing-boxes, a small area under steam pressure keeping all tight. The valves of the Wheelock engine have at one end a hardened steel trunnion and at the other a hardened steel bushing, valves, seats, and bushing-blocks being made tapering one way, and steam being allowed to pass back of the larger end of the valve to hold it to its seat and to take up wear.

In throttling-engines of the old type there is less need of balanced slide-valves, because the pressure of the steam as throttled is reduced. In well-governed throttling-engines proportioned for their loads there is less throttling, and balancing is more important, and in automatic engines with slide-valves some relief from the full pressure on the back of the valve is almost necessary An exception may be noted in favor of the Ball engine, in which the power of the governor is sufficient to actuate plain slide-valves, but even in this the work of moving the valves is to be considered as a cause of wear and a deduction from the power of the engine. The builders of this, as of most other automatic engines, recommend a balanced or relieved valve. A relieved valve is one which we define as partially balanced, enough pressure being permitted to hold the valve properly to its seat.

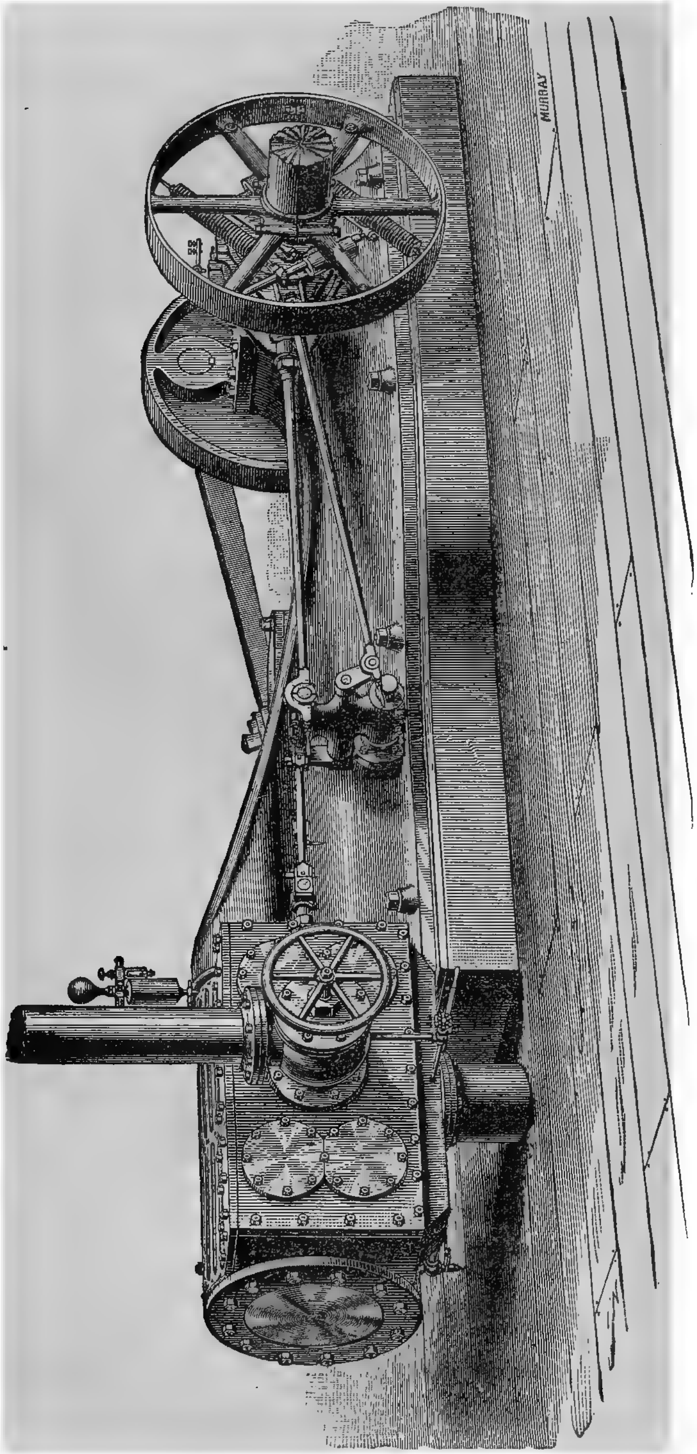


Fig. 22.—Buckeye Engine with Tangye or Porter Bed.

Builders of engines having flat valves will naturally refer to the locomotive, in the trying service of which "nothing else has been found to answer". The Porter-Allen engine has flat valves, the admission-valves being separate from the exhaust. The admission-valves have four places for the inlet of steam. The line of draft is central, which is conducive to long wear. Adjustable pressure-plates hold the admission-valves to their seats, being capable of movement on inclines to take up wear and yield for water relief.

The valve of the Straight-Line engine is a rectangular iron plate, with a back plate and side strips, in which, as a framing, the valve moves "practically frictionless". The back plate permits of compensation for wear and yields in case of water in the cylinder.

The Ball engine has a flat valve in two parts, between which is a packed piston. The arrangement partially relieves the pressure on the back of the valve and permits of automatic adjustment for wear. The valve-seat is rescraped during the testing of the engine until there is no leakage under full boiler pressure.

The Cummer engine has a flat main valve with a flat riding valve. These are small valves, with short movements, and the designers prefer such valves unbalanced to the complexity involved in balancing arrangements, relying upon the power of their governor to handle the valves easily, as it appears to do.

The Buckeye valve is peculiar in many respects. It is a relieved valve with a riding cut-off, and its success is attested by long usage. The main valve is of a box type, the interior of which is supplied with steam through open pistons, furnishing pressure areas, by which the valve is held to its seat. The cut-off valves are light plates working inside of the box-valve. Their stem works through the hollow stem of the main valve. To secure a nearer approach to a balance steam is admitted and exhausted from relief chambers in the valve-seat. The engine may be run with steam-chest covers off, and the tightness of the valves may be assured by inspection under steam.

The exhaust-valves of the Porter-Allen engine are self-tightening by steam pressure from the cylinder acting on a copper diaphragm, which holds the valves to their seats by a frame attaching to the diaphragm. This device is the invention of C. B. Richards.

The piston-valve furnishes the nearest possible approach to an absolutely balanced valve. It moves with little friction, and for its size and weight may be made to open larger admission areas than any other type. It is easily handled by shaft-governors, and has been adopted by many builders of engines so governed—the Westinghouse, the Ide, the Armington and Sims, the Beckett and McDowell, and numerous others. It is employed in the large rolling-

mill engine shown in Fig. 32, which has separate valves for admission and exhaust. These valves are liable to wear leaky, the hole, as is said, wearing larger and the valve smaller, but the valve has no less proved itself a practical working success. Some builders use packing-rings to maintain the tightness of the valves. These are employed in the Westinghouse valve, as shown in Fig. 30. The Beckett and McDowell engine uses Baxter's piston-valve, in which a wide bearing-ring may be set out uniformly by means of a follower with bolts drawing up circular and concentric wedges. The valve used in the Armington and Sims engine has no packing-rings nor adjustments for wear. It works in a bushing, which, like the valve, is replaceable at slight expense, and both are so finished and hardened to endure wear that they will last without leakage for years, such valves having been found to be perfectly tight after over 10 years of use.

Piston-valves and some types of balanced valves make no provision in themselves for the relief of water in the cylinder. To provide for this contingency the Ide engine employs diaphragm-caps screwed upon the cylinder,

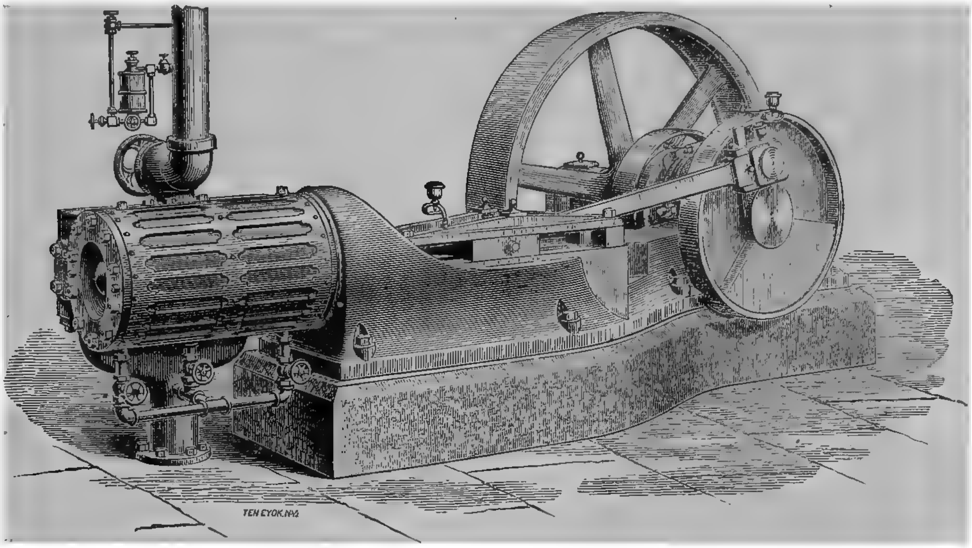


FIG. 23.—ARMINGTON AND SIMS ENGINE.

the diaphragms bursting before a dangerous pressure is reached. The Westinghouse engine employs a replaceable pop-out head set into the cylinder-head. In other engines pop-out plugs or water-relief cocks closing by springs are employed for the same purpose.

Frames.—If the valve-gearing embodies the most essential differences in the working organism of engines, the frame may be considered "the backbone of the engine," and gives it a characteristic appearance. Most large and long-stroke horizontal engines have modifications of the girder-frame. One of the earliest examples of this is shown in Fig. 14, the design of Horatio Allen. The framing is based on scientific principles and exhibits in its form the distribution of strains and the economical disposition of the material. The spreading web-footed stands, the curving bridge-like contour of the girder-spans, the stiff support under the guides, and the termination of main framing at the front cylinder-head, these may have some appearance of oddity to eyes familiar with later designs, but they are more correct than many of them. The comparatively slight support necessary for the cylinder is shown in the light stand, but for which this part of the engine would overhang. In Fig. 18 is shown a Corliss engine with cast-iron girder-frame. This is an ordinary style of framing, but of more than ordinarily graceful design. The stout post or foot supporting the end of the cross-head ways is a feature to be approved for rigidity in so long a girder, although it may be dispensed with in a shorter girder, as shown in Fig. 26.

In Figs. 19 and 20 wrought-iron frames are shown. The overhung-crank engine may be considered a one-sided construction, the strength of the frame being on one side of the main line of exertion of power, for which reason it has to be made the heavier. But in the construction shown the pillow-block support is extended in a large box-frame of cast-iron with heavy bosses for wrought-iron stretchers, extending to similar bosses on the cylinder-head and keyed at both ends. The resultant resistance to draft is central, and the stretchers are squared to serve as slideways for the cross-head.

In Fig. 32 we have an example of a cast-iron frame for heavy service, the usual girder being brought to the base in one continuous flanged foot.

The Straight-Line engine (Fig. 25) is a center-crank engine, deriving its name from the framing, which "runs in straight lines from the cylinder to the main bearings and exactly central with the line of strain, the frame resting on three self-adjusting supports, thus securing a constant true alignment".

Most of the early types of throttling-engines used a substantial framing, of which Fig. 16 is a good illustration. It may be called a box-frame. With sufficient weight of iron it is a good framing, steady, and with resultant resistance to draft central, but lacking beauty of outline, and not economical in its disposition of material. Fig. 15

shows a modification of this type, conforming more to the plan of the engine, but still with a solid box support under the cylinder. This engine had a very large sale at a time when a frame permitting the cylinder to overhang would have met with no favor.

For short-stroke engines, throttling and automatic, the Porter bed is the type coming into most general use. This is sometimes called the molded-rim bed, from the base being in one continuous rim from which the body of the frame ascends in gracefully-molded contour, but it is more often called the Tangye bed, from the English manufacturer, who followed the design exhibited by Mr. Porter at the Paris exposition (1867). The name is commonly used perhaps because it has a certain tang of foreign flavor, but the merit of the design belongs to Mr. Porter. Figs. 17, 21, 22, 23, 24, and 27 show engines with Porter beds. These frames are usually well stiffened with interior cross and longitudinal ribs, and the material is disposed so as to take the stresses and form a substantial base for the portion of the frame on which these stresses come. The cylinder is left to overhang, having only its own weight to support, which is little in comparison with the power exerted between the piston and the crank.

The Westinghouse engine, shown in Figs. 28, 29, and 30, is a peculiar type of vertical trunk engine, having an inclosed frame covering all the bearings, which are constantly bathed in a lubricating mixture of black West Virginia oil and water. The protection of bearings is particularly necessary in the surroundings of dust and grit under which engines are obliged to work in some manufactures. Watches have dust-proof cases, and the bearings of engines would often show better service if it were practicable to apply any such protection. The high speeds at which the Westinghouse engine easily works may be explained in part by the ample provisions for cooling the bearings, and the further progress of high speed may be thought to depend upon better facilities for lubricating, cooling, and even refrigerating the bearings, such as inclosing frames may permit us to employ.

Bearings.—In some cases the main bearing is capped at an inclined angle, but the best prevailing practice is to use four-part boxes, the caps horizontal, and the cheek-pieces adjustable by wedges and screws. A rigid support is obtained by making the bearing in a massive jaw in the bed, and giving broad surfaces to the cheek-pieces and adjusting wedges. In the Porter-Allen engine these wedges are located on either side at the edges of the bearings: so as to secure the greatest rigidity of support for the crank-shaft, the forces applied to which tend to deflect it.

In a main bearing provision has to be made for the resistance of forces and for wear in at least three directions: horizontally either way and vertically downward. The horizontal forces being greater than those due to gravity, the cap is sometimes placed vertically at the end of the bed to supply the greater adjustment. Great rigidity is, however, secured by bedding the bearing with substantial cheek-pieces in a solid uplooking jaw of the frame, and the adjustment for wear meets every practical requirement. In girder-frames, with slideways for vertical cross-heads, the top of the girder is brought much higher than the center of the shaft, as appears in Figs. 18 and 26. This permits and almost requires for good appearance a very deep and rigid cap, large enough to furnish a reservoir for lubrication.

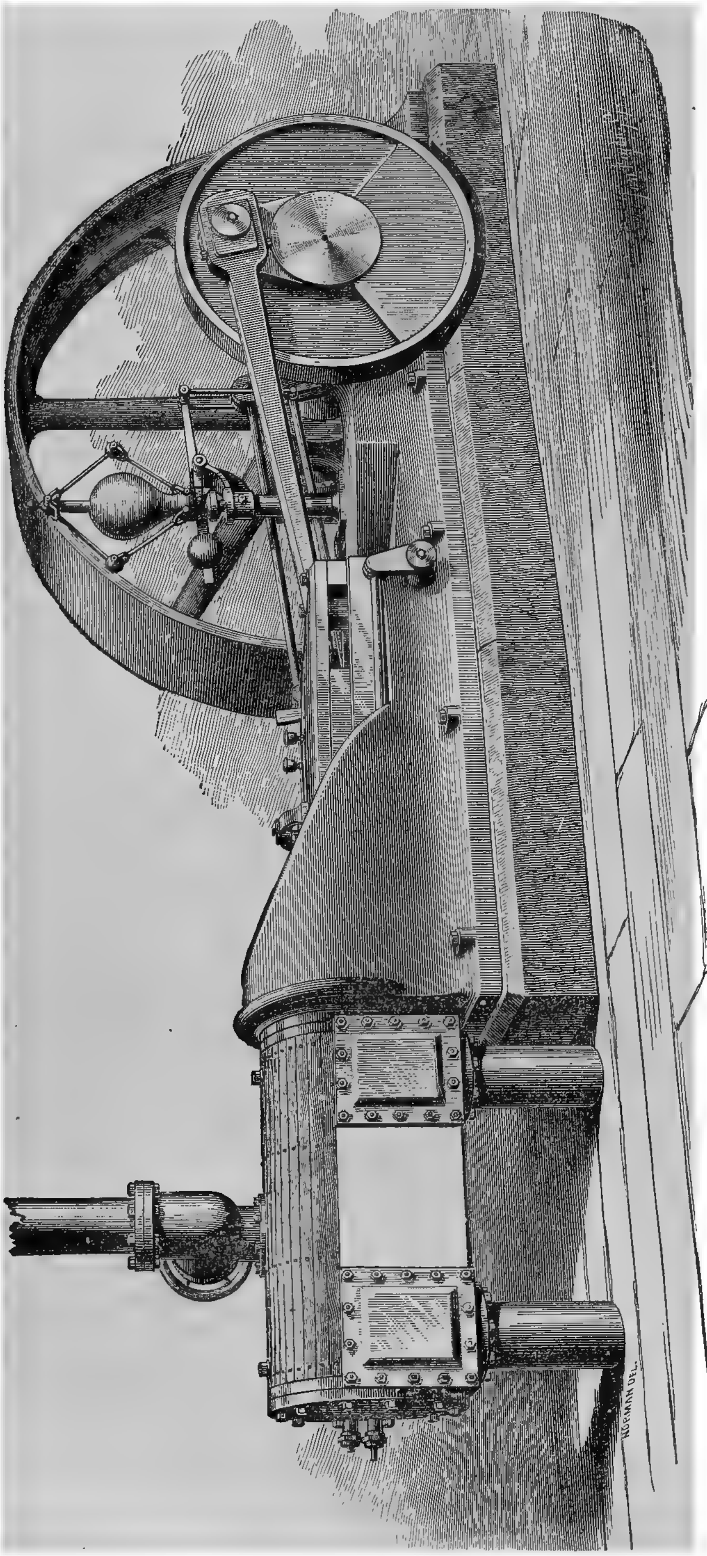


Fig. 24.—Porter-Allen Engine.

Brass boxes are sometimes used, but the use of babbitt is much more general and in every way satisfactory, if the metal be made from tin, antimony, and copper in correct proportions.

The main bearings of the Westinghouse engine are not made with boxes capped in the usual fashion, but sleeve-shells are used, babbitted, and firmly secured by taper sleeves and bolts. These shells are replaceable for wear, or may be rebabbitted. The method of making these babbitt linings is thus described:

> It was at first our practice to bore and ream the babbitt lining to an exact fit on the taper. Experience has, however, demonstrated that better results are obtained by retaining the natural skin or surface of the babbitt metal, which is found to have better anti-friction and wearing qualities than the softer metal beneath. But a lining of babbitt, which is simply poured around a mandrel, owing to shrinkage, may become loose in the box, and from the same cause may fail to show a fair bearing surface. To insure a hard, solid, and perfectly true bearing, the metal is poured around a mandrel, which is a little smaller than the shaft. When set, a taper steel mandrel, which is ground exactly true to the full size, is forced into the bearing up to a shoulder by a hydraulic press, which yields a net pressure of about 15 *tons to every square inch of the surface of the babbitt.* The shell being held in by a massive chucking ring, the metal is thus expanded into it with enormous force. Nothing can exceed the beauty and absolute truth of a bearing surface so obtained, and we feel justified in regarding it a mechanical process of great elegance.

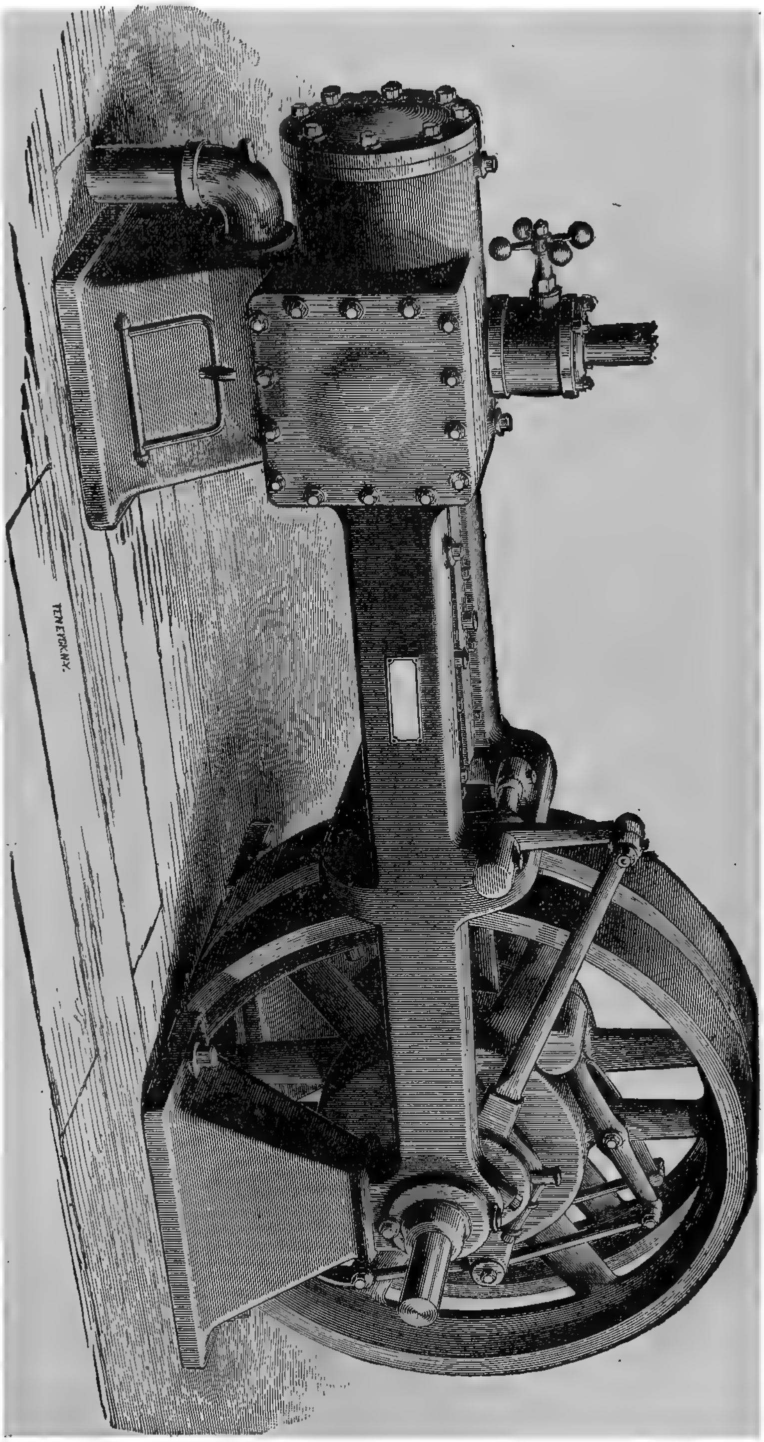


FIG. 25.—STRAIGHT-LINE ENGINE.

The slide-bearings, forming the cross-head ways, depend in form upon the type of cross-head. For vertical cross-heads, commonly used with girder-frames, and of a height permitting the oscillation of the connecting-rod between the webs which support their ways, the bearings are sometimes bored out, but are more often flat slides, or slides converging at an obtuse angle for purposes of lubrication. Flat slides, with proper channels, seem to furnish every requisite for good lubrication and enduring service. Replaceable steel strips are sometimes used, but hard, fine-grained cast-iron is very durable, and can hardly be bettered by steel. Frames are sometimes cast of iron which is very strong but porous, so that the guides planed in the metal show a surface which wears out cross-head shoes very rapidly. In such a case strips of steel or of smooth cast-iron are almost necessary.

For high-speed engines the locomotive type of cross-head, with its flat bar guides, is commonly employed, and in point of durability nothing more could be desired.

The power-train.—The moving parts, through which the pressure and work of steam is transmitted to the main shaft, may be defined as the power-train, comprising in most steam-engines approved by large usage several standard parts: the piston with its rod, the cross-head, the connecting-rod, and the crank.

In pistons the tendency seems to be in the direction of liberal depth and simplicity in packing. Long-stroke engines commonly employ some form of jointed segmental rings pressed out by springs, of which there are a number of approved types, the Babbitt and Harris packing being largely used. With the high-speed engines, small snap-rings are almost universally used, as in the Porter-Allen, the Straight-Line, the Westinghouse, the Armington and Sims, the Ball, and other engines. In the Westinghouse engine, as is usual in trunk-engines, the piston, serving also as a cross-head, is made of extra depth, to provide sufficient bearing-surface. In the pistons of long-stroke engines followers are used, but the high-speed engines have usually pistons that are solid or cored out hollow and plugged after removal of the core.

The standard method of securing piston-rods in the pistons is by means of a taper fit, terminated with a screw and nut. In some engines the rod is screwed and shrunk into the piston.

In considering the cross-head we are first brought to the question of equalization of effort upon the crank-pin by giving weight to the reciprocating parts, chiefly the cross-head and the piston. Two entirely different principles of design prevail, of which, in this respect, the Porter-Allen engine and the Straight-Line engine may be considered representative types. Referring to the Porter-Allen engine, we quote: "No amount of testimony", said Mr. John Hick, then the leading builder of stationary steam-engines in England, after he had come every day for a fortnight and watched one of these engines in the Paris exposition of 1867 running with 24-inch stroke at 200 revolutions per minute—"no amount of testimony would have made me believe that a steam-engine could be made to run at that speed with such absolute smoothness". "The secret of it", adds Mr. Porter, "was the inertia of the reciprocating parts between the steam and the crank".

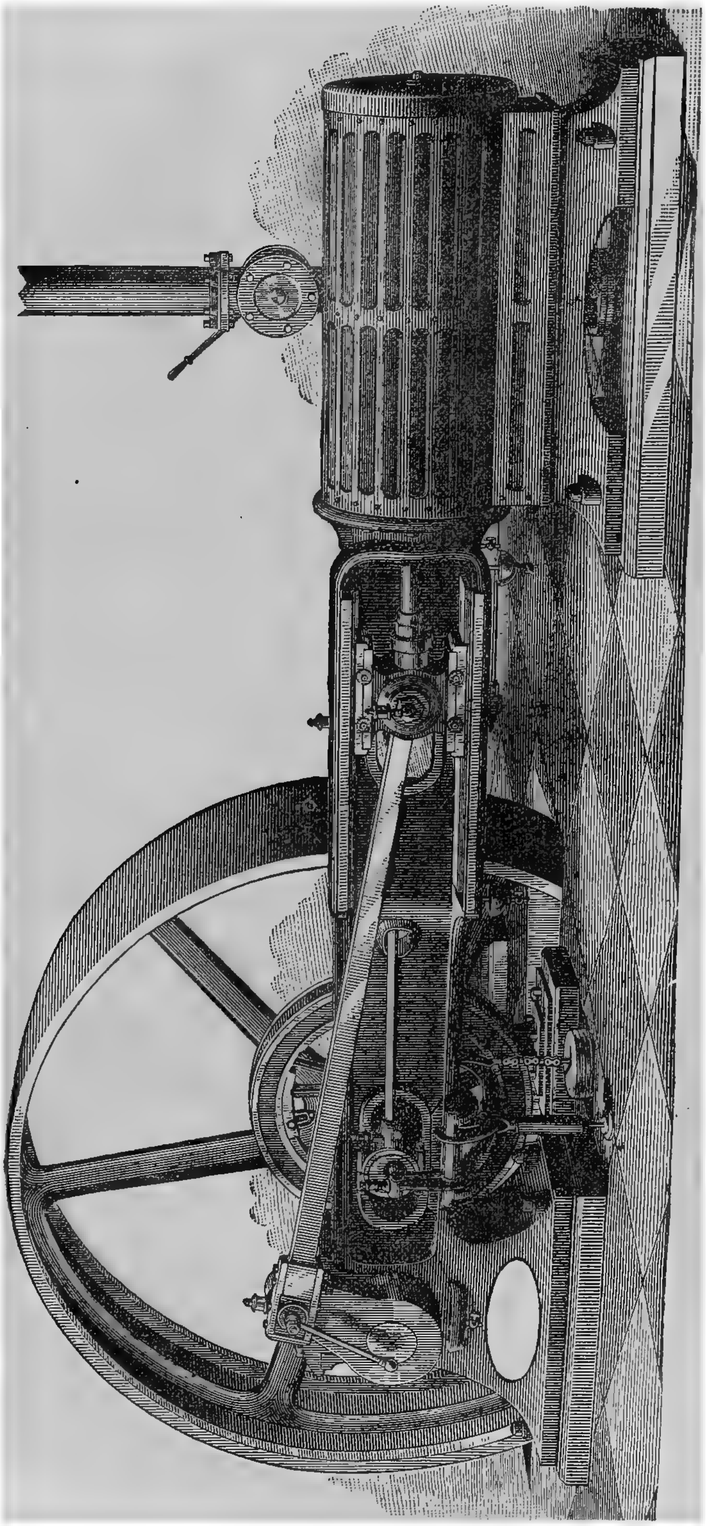


Fig. 26.—Cummer Engine.

This is explained as follows: At the beginning of the stroke of an engine there is full pressure of steam on the piston. This pressure has to meet the continuous resistance of the work upon the engine. It has also to overcome the inertia of the reciprocating parts, which must be brought from rest to the speed of the crank-pin between the beginning and the middle of the stroke. When mid-stroke is reached, the steam having been cut off, the pressure of steam in the cylinder has fallen by expansion, and as this pressure continues to decrease, the reciprocating parts, in slowing from the speed of the crank-pin to no speed at the other dead-center, by their inertia exert a pressure which helps the decreased steam pressure. By making the reciprocating parts of such a weight that their initial acceleration requires a pressure about half that of the initial steam pressure, the effort at the crank is made nearly uniform throughout the stroke.

The facts of the action of inertia are unquestioned, but the desirability of producing a uniform effort upon the crank-pin throughout the stroke does not meet with universal concurrence. Engines which are constructed with the reciprocating parts as light as consistent with durability and strength are run with great smoothness at high speeds, and not a few builders, even some who mention the virtue of a "reciprocating fly-wheel" in their advertisements, in design take a middle ground, giving the parts a weight with which the uniformity of effort obtainable is only partially realized. The beneficial effect of inertia in the reciprocating parts in the earlier part of the stroke is supplemented in the latter part by a suitable compression, which cushions the effort upon the crank-pin down to little or nothing as it approaches its dead center. The maximum effort upon the crank-pin may be much reduced by properly loading the reciprocating parts.

The practical outcome of the advantages described may be overrated, for, on the other hand, we have light parts working with less friction. The variations in successively reversed impulses have less to do with smooth running than the fact of high rotative speed itself, which not only greatly increases the regulating power of the fly-wheel, but secures uniformity, by substituting for a few long and heavy impulses, in the same time, a great number of short and light impulses. As this subdivision increases, the character of the strokes in respect to the graduations of effort during their brief continuance becomes of less and less moment.

Cross-heads are chiefly of three types: the vertical, having bearing-surfaces above and below a central eye; the slipper, having a bearing-surface below the eye of the cross-head pin; and the horizontal or locomotive type, having double bearings on either side, with the eye of the cross-head pin in the middle. Those most commonly in use are the vertical cross-heads for girder-beds and the locomotive type of cross-head for Porter beds. The vertical cross-heads are either turned or planed, and are usually provided with means of adjustment by screws and set-nuts, or by wedges with screws and set-nuts. The wear is very slow. In the Ide engine the only compensation thought necessary may be obtained by laying a thin strip of paper or metal between the body of the cross-head and the lower shoe.

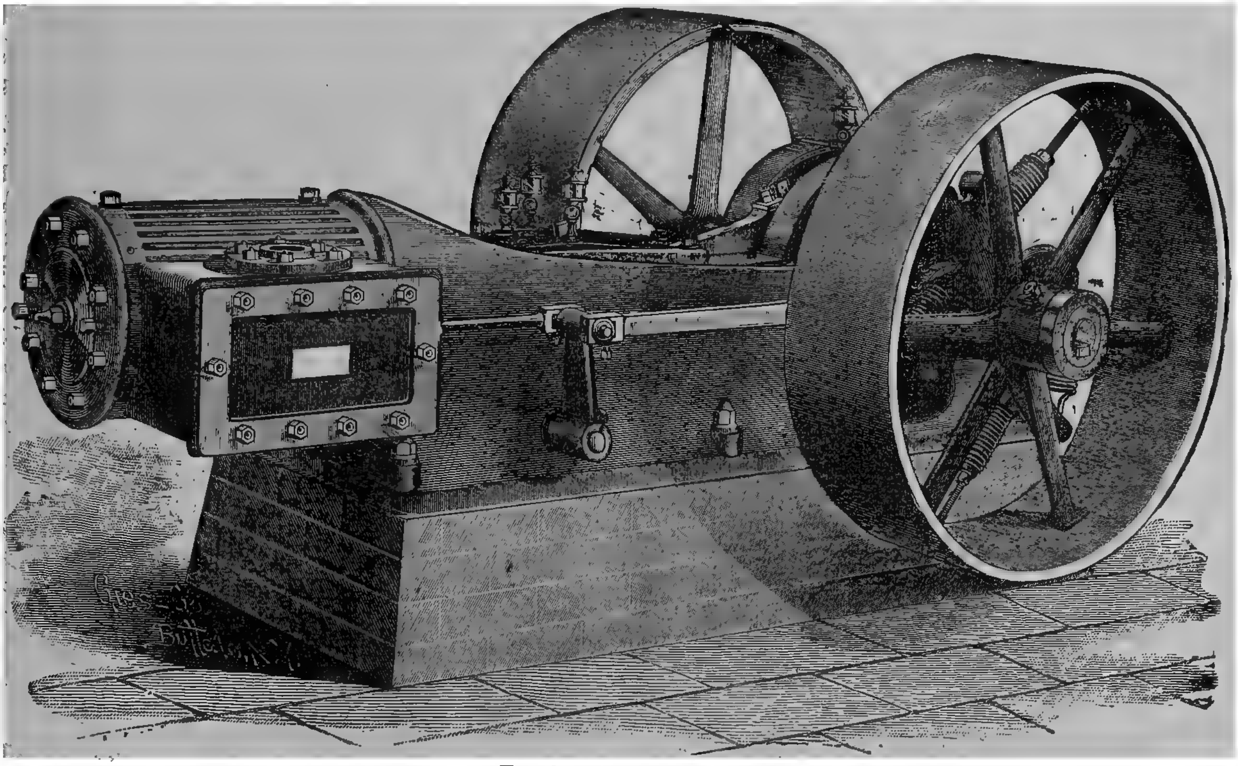


FIG. 27.—BALL ENGINE.

Equilibrium valves of the rectangular piston type will wear more or less variably from steam flow or other causes, but cast-iron cross-heads of the locomotive type, with large bearing-surfaces and kept clean (though similar in form), are said never to wear. This may not be absolute, but there are engines which have been running for a quarter of a century which are declared to have had no adjustment of such wearing-surfaces. An engine with running-gear of the type shown in Fig. 17 has been in active service over 16 years with "no wear at all", that is, no appreciable wear, upon the sliding surfaces, and the cross-head travel at high speed has covered a prodigious distance in this time. In the Porter-Allen and other engines using this type of cross-head it is not thought necessary to provide any adjustment for wear.

The lubrication of cross-heads is accomplished by the use of oil-cups upon the upper guides, with ways for carrying the lubricant from the upper to the lower sliding surfaces and distributing it upon both. The oiling of the pin may be accomplished in the same way, or a separate oil-cup may be used, reciprocating with the cross-head or mounted upon the head of the connecting-rod. Continuous oiling from a stationary cup is secured by the use of wipers, which pass a drop of lubricant at every stroke.

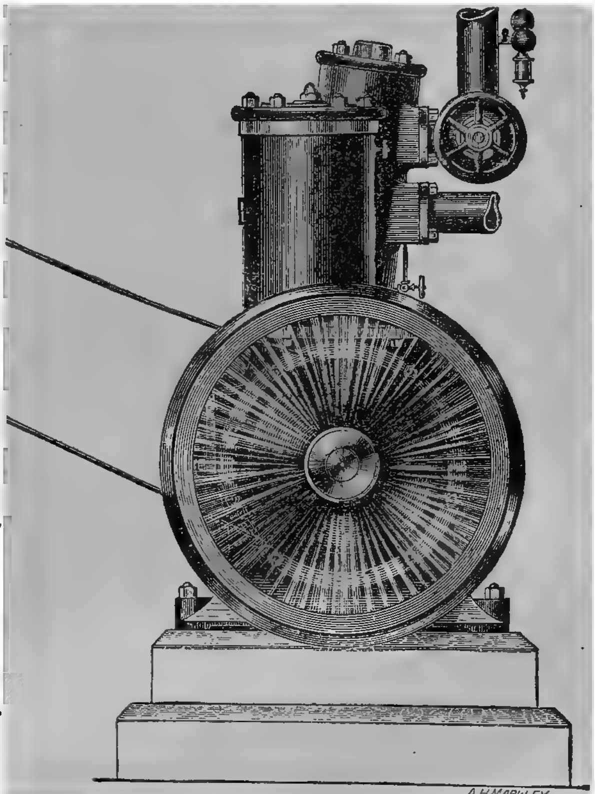


FIG. 28.—WESTINGHOUSE ENGINE.

The standard method of securing the piston-rod in the cross-head is by means of a key, but a screw with set-nut is not unfrequently used, and the Buckeye and Straight-Line engines have peculiar methods of securing the rod. In the Buckeye the cross-head (of the vertical type) is in halves, which are pinched upon the thread of the piston-rod by

bolts. The construction is neat and safe, hiding the thread, and requiring no set-nut. In the Straight-Line engine two sides of the rod and two sides of the nut in the cross-head are slabbed off, so that a quarter turn will release the rod after removing two clamp-bolts, which pass close to its flattened sides and hold it securely in place.

The cross-head pin is generally placed in the center of the length of the cross-head, to avoid any tendency to spring the piston-rod. The pin is commonly fixed in the cross-head and is a center-pin, upon which the end bearing of the connecting-rod turns. The Straight-Line engine is peculiar in having the pin-bearings with adjustable boxes in the cross-head, the pin being fixed in the end of the rod, and a modified design dispenses with these boxes by making the adjustment in the pin itself, in which the bearing sides may be spread apart by taper wedges operated by bolts. Cross-head pins are sometimes turned solid, but are more often of steel let into the cast-iron head and secured by bolts. They are flatted top and bottom, the wear coming upon the sides. The Ide engine is exceptional in using a round pin, which may be turned to equalize wear. This is secured by a split taper sleeve and screw and nut on one side drawing up against a taper of the pin in the opposite cheek of the cross-head.

The standard form of connecting-rod end is that in which brass boxes are secured by a steel strap with gib and key and set-screw. In other types the stress is taken by bolts with a key for adjusting the boxes. A type in

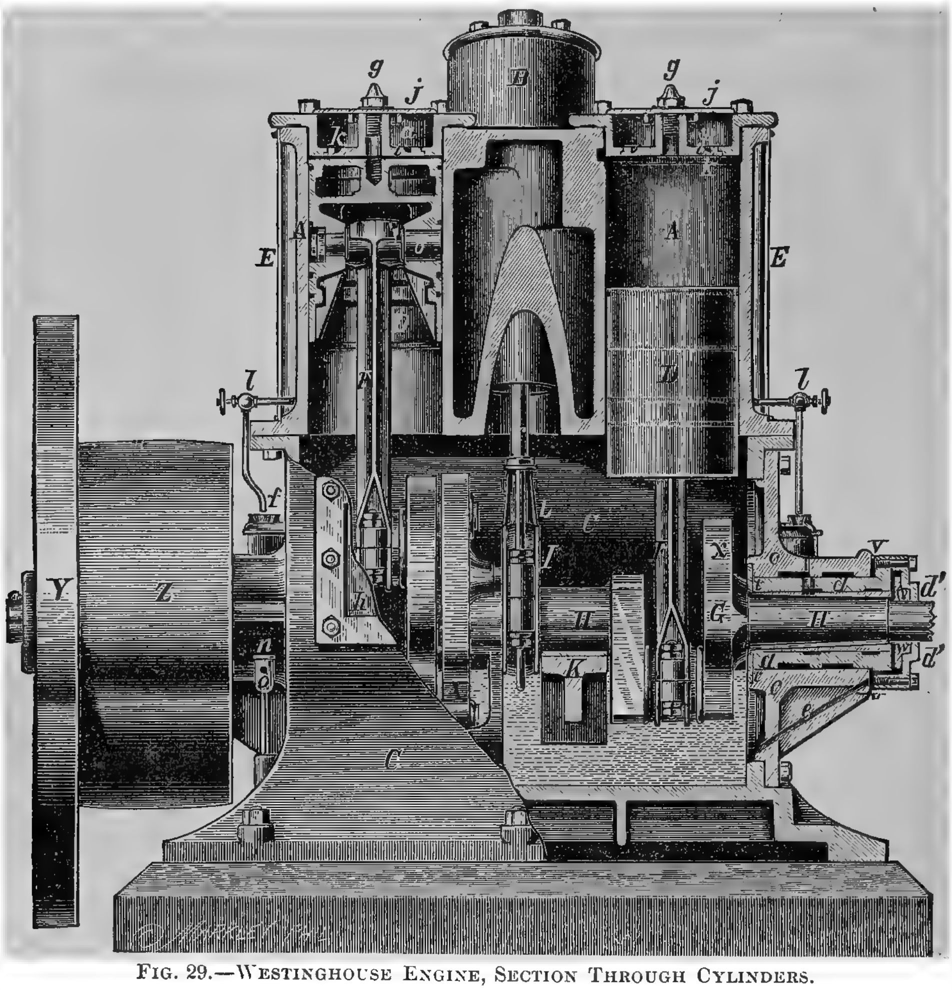


FIG. 29.—WESTINGHOUSE ENGINE, SECTION THROUGH CYLINDERS.

growing favor is styled the "solid end" rod, in which no strap is used, the brass boxes being let into an opening in the head of the rod, with adjustment by broad flat wedges held in position by screws or by through-bolts.

The greater vibration at the crank end of the rod increases any liability to loosen a key at that end. We therefore often find the usual strap, gib, and key at the cross-head end, while at the crank end the solid type with wedge is used, or the marine type, in which a bearing-cap is bolted down over the half boxes of the pin endwise.

Where keys or wedges are used at either end of the connecting-rod they are so placed that the wear of boxes at one end will compensate for that at the other and preserve the length of connection nearly unchanged. Single action, as in the case of the Westinghouse engine, avoids the reversal of stresses. This requires ordinary connecting-rods to be carefully keyed up, heating resulting if the boxes are set too tightly and pounding if they are left at all loose.

The connecting-rods of American engines are usually of liberal length, being commonly more than five and often six or more cranks long, so that the stresses upon the guides are reduced. The ratio of connecting-rod to crank does not average as high in foreign engines. In the Westinghouse engine another advantage of single action is realized in offsetting the shaft from the center line of cylinder, so that the angular vibration of the rod is

greatly reduced while under stress from the steam pressure, which acts only on one side. This is tantamount to using a connecting-rod about ten cranks long without taking up the space which would be occupied by such a connection.

In large stationary engines a usual method of proportioning the crank-shaft bearings is to make them of a diameter equal to half the diameter of the cylinder and of a length equal to the diameter of the cylinder. Increased stiffness is commonly secured by giving the shaft a greater diameter between bearings. As engines are speeded higher the overhang of the crank-arm and pin become proportions which it is desirable to reduce as far as possible. The crank-pin may be made larger and shorter, and the crank itself may spread into a counterbalanced disk, as in the Porter-Allen engine. The plain disk-crank is used in many engines, especially in plain slide-valve engines running at high speeds, but in the automatic engines of low rotative speed the ordinary single crank is used. For high speeds there is only one step beyond the disk, and that is the double crank or the double disk. This we see in one form of the Armington and Sims engine, and it is also a feature of the Straight-Line engine, in which the cranks are made to play the part of fly-wheels.

Crank-pins are variously secured: by bolting, shrinking, or riveting, and cranks are commonly keyed upon their shafts. An ingenious method of centrifugal oiling was first introduced as a feature of the Buckeye engine. A hole is drilled lengthwise of the crank-pin and a smaller one radially outwards to the bearing. A tube extends from the former hole to the center of rotation, and oil delivered into a stationary ball at the end of the tube is carried by centrifugal force to the crank-pin bearing. In the Straight-Line engine a centrifugal feed is also used, the oil being delivered into an annular recess in the crank-hub, from which it is carried to the pin. In the Porter-Allen engine stationary lubricators are used, all moving parts being lubricated by wipers without the use of wicks. Reference has already been made to the inclosure of working parts in a lubricating-reservoir as employed in the Westinghouse engine.

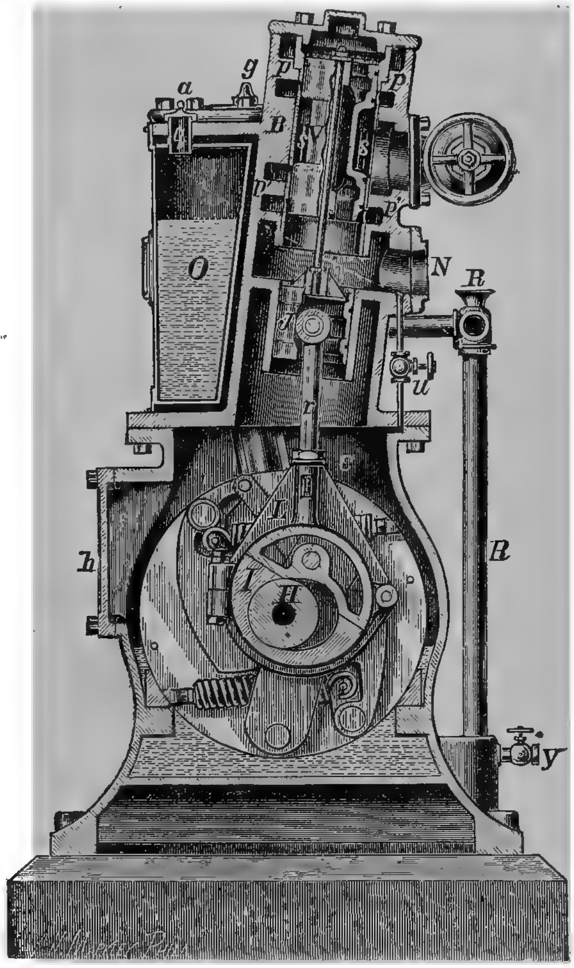


Fig. 30.—Westinghouse Engine, Section Through Valve-Chest.

In packing piston-rods and valve-stems there is substantially no variation in the usage of flexible packing material set up by glands except in the case of the Straight-Line engine, in which the piston-rod is ground and works through a reamed hole in a very long bushing of compressed babbitt "without contact and steam-tight". The bushing is spring supported and free to move, and the valve-stem is also ground and works in a long babbitt bushing, the aim of the designer being to produce an engine which should require no packing.

Evidence of design.—Before leaving the consideration of engine details, which might be dwelt upon at much greater length, it is worthy of remark that the novel features introduced in American practice are more than simply ingenious. They show a distinct avoidance of complexity and a careful adaptation of the means to the end. The most radical departures from previous practice are found to be based on the conclusions developed from the study of scientific principles, and they have been pushed to success in opposition to a great deal of prejudice based on the pre-existing condition of things.

Much thought has been devoted to the design of engines which will lessen the necessity for skillful care and with features which will not permit of tampering. One builder claims his engine as "remarkable for what the engineer cannot do to it". Another guards against the mischief to which such machinery is liable from "the indiscriminate use of the monkey-wrench". Another casts upon his valves the warning words: "Let me alone." One builds an engine which requires no packing, and another, one which requires no keying-up, and not a few provide methods of continuous lubrication. Yet with all these precautions intelligence in the management of engines remains so important a factor, that the lack of it causes vastly more loss of power than the inherent defects of engines.

Economy in the use of steam.—There are some usages in the employment of steam for power which if intelligently applied would result in an enormous aggregate saving. While the marketing of engines of various designs has been actively furthered, the application of methods of economy, more or less available with all designs of engines, has not received due attention. These are chiefly superheating, steam-jacketing, the use of condensers, and compounding.

Steam-jacketing "increases the economy of an engine by supplying such an amount of heat to the interior walls as to prevent the condensation upon them of the entering steam, and although the amount of steam condensed in the jacket is very great, it is far less than that which it prevents. The best experiments show a saving of from 8 to 10 per cent. with well-loaded engines, and 15 per cent. or more with engines having a light load and excessive expansion". (H. A. Hill.)

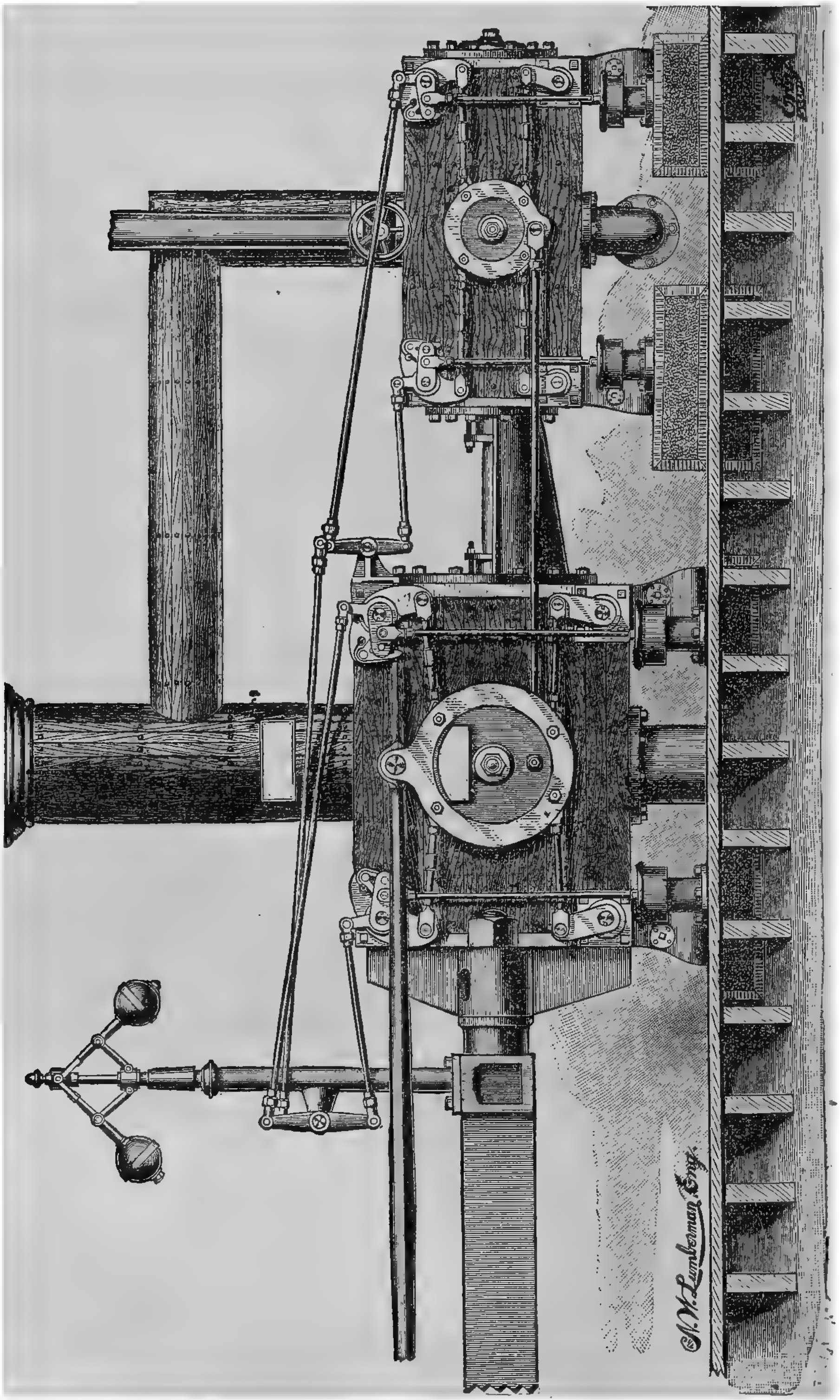


FIG. 31.—COMPOUND CORLISS ENGINE (MILWAUKEE, WISCONSIN).

Steam-jacketing is a less radical and less effective means of preventing cylinder condensation than superheating the steam. To the practical value of superheating and its proper application Mr. Charles T. Porter has given particular attention, and Mr. J. C. Hoadley has invented a form of boiler which affords a safe and reliable means of obtaining the moderate degree of superheat which is beneficial. Excessive and uncontrolled superheating will

destroy packing and ruin an engine, but in the Hoadley device the degree of superheat is tempered and limited. It gives a temperature of 371 degrees to steam of 90 pounds pressure, which saturated has a temperature of 331 degrees.

Compounding, or the employment of more than one cylinder in which to utilize the expansion of steam, has a decided value. It lessens internal condensation by limiting the changes of temperature in any one cylinder. It

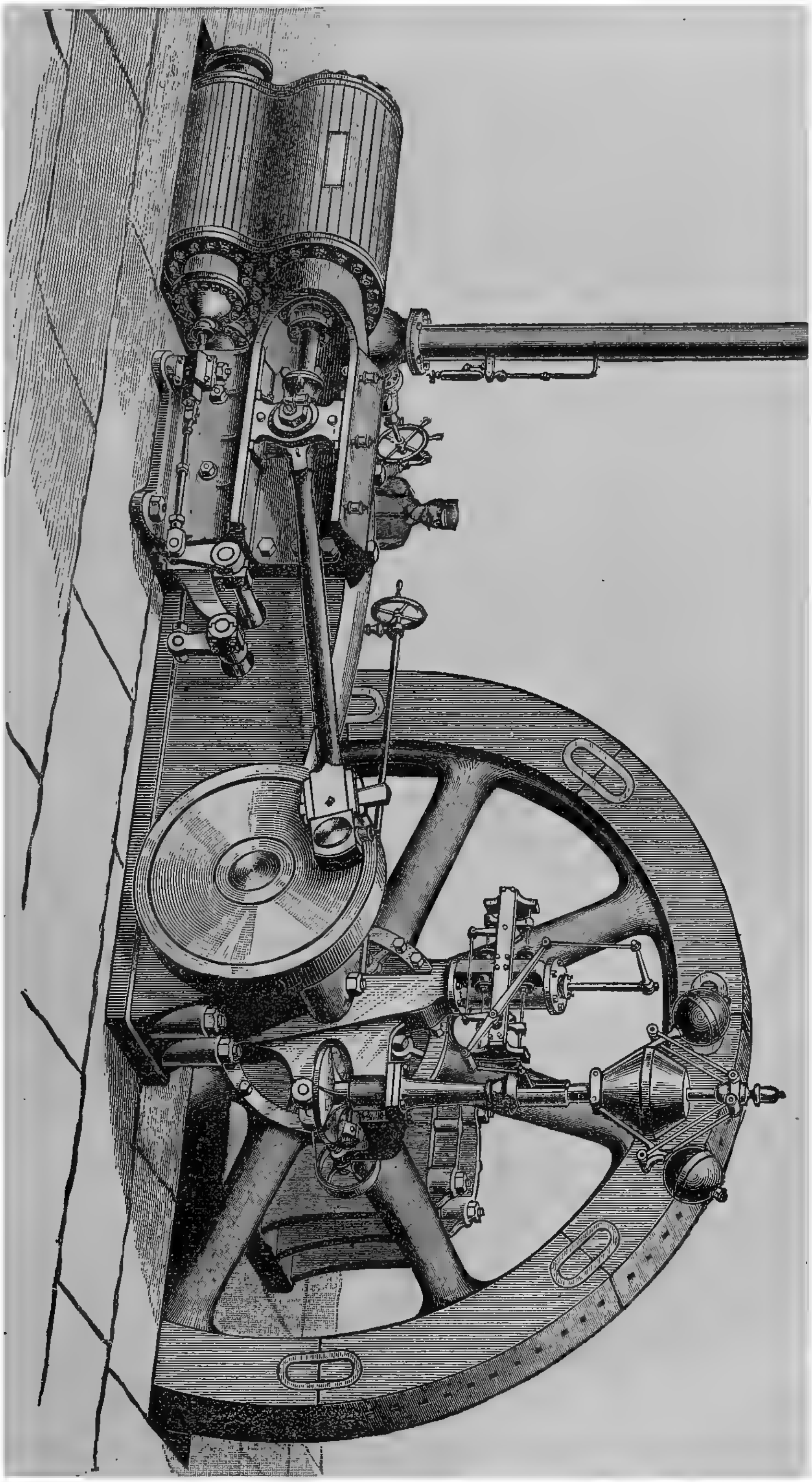


FIG. 32.—HEAVY ROLLING-MILL ENGINE.

also permits the use of such a ratio of expansion as will not render the clearance space so great relatively to the full admission as to cause a loss which cannot be easily remedied by compression. The transfer of steam from a smaller to a larger cylinder in the course of expansion involves a loss. Mr. Porter says: "There being no boiler to furnish an unlimited supply (note—as in ordinary high-pressure cylinders), but the supply being only the

quantity discharged from the first cylinder, this loss from the condensation of the entering steam stands revealed. This fall of pressure is hardly ever less than eight pounds. I have known it to be as much as twenty-five pounds, representing a corresponding loss of heat". The remedy for this loss is found in the use of an intermediate receiver in which the water of condensation is drained off while the remaining steam is heated by a jacket.

In Fig. 31 is shown Mr. Edwin Reynolds's arrangement for compounding Corliss-engine cylinders, as built by E. P. Allis & Co. Here the cylinders are placed in "tandem" order, instead of being side by side with separate crank connections, as in the case of the Porter engines, to which the above-described steam-jacketed receiver is applied.

Respecting the Allis engines it is said:

Repeated trials and tests have shown that with a compound condensing-engine properly proportioned to the load and steam-pressure a saving of 40 per cent. can be effected over a non-condensing-engine and 15 per cent. over a condensing-engine in the steam and fuel used to do a certain work. The steam is first admitted to the high-pressure cylinder, where it is expanded down to within 4 to 6 pounds of the atmosphere; it is then released into the receiver; from the receiver it passes to the low-pressure cylinder, where it is expanded a second time to about 9 pounds below the atmosphere, when it is released to pass to the condenser, thus forming a nearly continuous line of expansion from the boiler pressure down to 9 pounds below the atmosphere.

The gain obtainable by condensing may be reached without so great an outlay for machinery as is required for compounding. The air-pumps necessary are sometimes operated by connection with the cross-head or the main shaft of the engine. With the Porter-Allen engine the air-pump is driven by a belt through gearing, and in mid-summer, with the warmest injections, the power required to drive it does not exceed 1 per cent. of the power of the engine. Independent condensing apparatus with air-pumps operated by direct-acting steam-engines are considerably used, the Worthington, the Deane, the Knowles, and the Blake being familiar types. These employ jet-condensers, requiring under ordinary temperatures a weight of water 20 to 25 times the weight of steam condensed. The recent invention of a surface-condenser (F. M. Wheeler's), in which the difficulty of leakage of tubes is obviated, promises to be of advantage under some circumstances. The gain of power from condensing alone may be reckoned at from 20 to 50 per cent. Yet an engine running under a light load and with high boiler pressure may derive little or no benefit from a condenser, which would only serve to give it an earlier cut-off with a very serious increase of internal condensation.

The following account of trials of an automatic engine in a flouring-mill (Gibson & Co., Indianapolis, Indiana), made by John W. Hill, M. E., 1877, and published in *Van Nostrand's Magazine*, affords an interesting comparison of the performance of an engine condensing and non-condensing upon nearly the same work:

Twelve run of 48-inch buhrs do the grinding; these are driven by belts, the line-shaft being coupled to end of engine-shaft, and revolving at same speed; the balance of machinery, cleaners, rolls, elevators, conveyers, bolts, purifiers, and packers, are all adapted to maximum capacity of grinding machinery.

The engine is a Harris-Corliss single cylinder, 18 by 42 inches, speeded at 75 revolutions, with a 12,000-pound fly-wheel, 16 feet diameter.

The boilers were opened and cleared of scale and sediment previous to trials.

The coal fired is known as Highland (Clay county), a species of the celebrated Indiana block coal.

During both runs the mill was worked at maximum capacity, quality and condition of wheat considered. It may not be out of place to remark that in this mill the Messrs. Gibson made what is known as patent process flour; thus of the 12 run of buhrs, 7 run operated on wheat, and 5 run on middlings, bran, and tailings. In making flour by this process it is customary to grind 7 to 8 bushels of wheat per hour per run of buhrs (48-inch); during the trials 7.5 to 8 bushels of wheat were ground per hour per run (wheat stones).

The record of work in the mill was based on the barrels of flour packed; this being regarded as an approximate index of the amount of work done by balance of machinery; the amount of work done by storage elevator was greatest during non-condensing run.

Hourly reports of condition of machinery in the mill were made by the chief miller, and entered in the writer's notes. The following table exhibits the amount of machinery driven and disposition during each run:

TRIAL CONDENSING.	TRIAL NON-CONDENSING.
Started 7.30 a. m., August 22.	Started 8.15 a. m., August 24.
7 run on wheat; 3 run on middlings; 2 run on red dog.	7 run on wheat; 3 run on middlings; 2 run on bran.
Cleaner.	Cleaner.
Rolls (2).	Rolls (2).
Bolts (all).	Bolts (all).
Purifiers (5).	Purifiers (5).
Elevators and conveyers (all).	Elevators and conveyers (all).
Packer (1).	Packer (1).
At 9.15 a. m., lightered 3 run on middlings.	Storage elevator.
At 10.15 a. m., changed 2 run from red dog.	At 8.30 a. m., changed 2 run from bran to red dog.
At 10.30 a. m., storage elevator on (to) bran.	At 9.55 a. m., changed 2 run from red dog to bran.
At 10.30 a. m., lightered 2 run on bran.	Storage elevator irregular.
At 1 p. m., storage elevator off.	Stopped 4.15 p. m.
Stopped 3.30 p. m.	

REMARKS.—Starting and stopping in above table merely denotes the time run was held to commence and end. The engine and machinery ran without interruption.

Performance of engine.

	Condensing.	Non-condensing.
Duration of run ... hours..	8	8
Pressure in the pipe ... pounds..	58.50	76.37
Temperature of injection ...	81.80	....
Temperature of hot well ...	112.00	....
Temperature of steam at terminal pressure ...	203.19	....
Barometer (assumed) ... inches..	29.53	29.53
Vacuum in condenser ... do...	21.83	....
Revolutions ...	74.288	73.600
Piston speed ...	520.016	515.200
Horse-power due piston speed ...	3.954	3.917
By the diagrams.		
Initial pressure (above atmosphere) ...	57.015	74.042
Cut-off in parts of stroke (stroke 100) ...	10.827	18.891
Release in parts of stroke (stroke 100) ...	100.000	99.000
Terminal pressure (absolute) ...	12.329	19.581
Counter-pressure (absolute) at mid-stroke ...	4.594	15.933
Exhaust closure in parts of stroke ...	3.478	8.816
Mean effective pressure ...	26.928	29.471
Friction pressure (assumed) ...	1.962	1.962
The power.		
Indicated horse-power ...	105.473	115.437
Friction horse-power ...	7.757	7.685
Gross load horse-power ...	97.716	107.752

	Condensing.	Non-condensing.
Extra friction horse-power due to load ...	4.885	5.387
Net effective horse-power ...	92.831	102.365
Per centum of indicated power available ...	88.014	88.684
Economy.		
Net steam per hour to engine ...	1961.03	2931.14
Net steam per hour per indicated horse-power ...	18.593	25.391
Net steam per hour per indicated horse-power by the diagrams ...	16.587	21.983
Per centum steam accounted for by indicator ...	89.211	86.578
Cost of the power.		
Coal per indicated horse-power per hour ...	4.085	5.213
Coal per indicated horse-power per hour, evaporation 9 to 1.	2.076	2.832
Relative efficiency ...	100.00	73.30
Economic gain by use of vacuum ...	36.41	....
Cost of the flour.		
Barrels ground and packed ...	89	93
Horse-power per barrel per hour ...	9.480	9.947
Coal per barrel (actual) ...	38.73	51.76
Coal per barrel (evaporation 9 to 1) ...	19.71	28.11
Relative efficiency ...	100.00	74.826
Economic gain by use of vacuum ...	33.34	....

The following tables of engine performance are taken from a publication of the Buckeye Engine company, Salem, Ohio. They show for three points of cut-off under specified initial pressures the resulting mean effective pressures for condensing and non-condensing engines, the terminal pressures, and the steam or water consumption with condensing and non-condensing automatic- and throttling-engines. The steam consumption is given in pounds per horse-power per hour. The rates marked "theoretical" are computed from indicator diagrams, those marked "actual", from experiment, in part, some of the figures being obtained by plotting curves through points established by the known data:

CUT-OFF $\frac{15}{100}$.								CUT-OFF $\frac{1}{4}$.								CUT-OFF $\frac{1}{2}$.								
Mean effective pressures.			Rates.					Mean effective pressures.			Rates.					Mean effective pressures.			Rates.					
			Actual.		Theoretical.						Actual.		Theoretical.						Actual.		Theoretical.			
Non-condensing.	Condensing.	Terminals.	Non-condensing.	Condensing.	Non-condensing.	Condensing.	Throttling.	Non-condensing.	Condensing.	Terminals.	Non-condensing.	Condensing.	Non-condensing.	Condensing.	Throttling.	Non-condensing.	Condensing.	Terminals.	Non-condensing.	Condensing.	Non-condensing.	Condensing.	Throttling.	Initial pressure.
9.05	19.05	9.07	54.0	30.0	31.3	16.8	64	17.34	27.34	14.49	39.0	22.0	27.2	18.5	46	30.50	40.50	27.78	41.0	29.5	28.5	23.4	39	40
11.32	21.32	9.87	47.0	28.5	27.7	16.4	56	20.39	30.39	15.81	36.0	21.5	25.3	18.2	44	34.75	44.75	30.33	39.0	28.8	27.6	23.1	38	45
13.59	23.59	10.72	42.0	27.0	25.3	16.1	51	23.45	33.45	17.13	33.5	21.0	24.0	17.9	42	39.00	49.00	32.88	37.0	28.3	26.9	22.8	37	50
15.86	25.86	11.55	38.0	26.0	23.4	15.8	47	26.50	36.50	18.45	31.2	20.5	22.9	17.6	40	43.25	53.25	35.43	35.5	27.9	26.3	22.5	36	55
18.12	28.12	12.38	34.5	25.0	22.1	15.6	43	29.56	39.56	19.77	29.0	20.0	22.0	17.4	39	47.50	57.50	37.98	34.0	27.5	25.8	22.2	35	60
20.39	30.39	13.20	32.0	24.0	21.1	15.4	40	32.61	42.61	21.09	27.6	19.5	21.3	17.2	38	51.75	61.75	40.52	32.5	27.1	25.3	22.0	34	65
22.66	32.66	14.03	30.0	23.0	20.3	15.2	38	35.67	45.67	22.41	26.4	19.0	20.8	17.0	37	56.00	66.00	43.07	31.0	26.7	24.9	21.8	33	70
24.92	34.92	14.86	28.0	22.2	19.5	15.0	36	38.72	48.72	23.73	25.3	18.5	20.4	16.8	36	60.25	70.25	45.61	30.0	26.3	24.5	21.6	32	75
27.19	37.19	15.69	26.0	21.3	18.8	14.8	35	41.78	51.78	25.05	24.0	18.0	20.0	16.6	35	64.50	74.50	48.16	29.0	25.8	24.2	21.5	31	80
29.46	39.46	16.51	24.5	20.4	18.4	14.6	34	44.83	54.83	26.37	23.0	17.7	19.6	16.5	34	68.75	78.75	50.70	28.0	25.4	23.9	21.4	30	85
31.72	41.72	17.34	23.0	19.5	18.0	14.5	33	47.89	57.89	27.69	22.0	17.4	19.3	16.4	33	73.00	83.00	53.25	27.0	24.9	23.7	21.3	30	90
33.93	43.93	18.17	22.0	18.7	17.6	14.4	32	50.94	60.94	29.01	21.2	17.2	19.0	16.3	32	77.25	87.25	55.79	26.0	24.5	23.5	21.2	29	95
36.26	46.26	19.00	21.0	18.0	17.3	14.3	32	50.04	64.00	30.33	20.4	17.0	18.7	16.2	31	81.50	91.50	58.34	25.0	24.0	23.3	21.1	29	100

The steam consumption for the throttling-engines is when running with the same boiler and mean pressures as the non-condensing engines of the same lines.

SIZES OF ENGINES USED IN VARIOUS MANUFACTURES.

The following figures show the average sizes of engines used in the specified industries in 1870, and are of value in indicating the sizes and powers used in these various industries, and the relative cost of power entering into the various products. The total power (water and steam) in respect to the value of product is shown by taking the total horse-power per hour by the number of hours for 300 days, divided by the value of the product in dollars. The average number of operatives per establishment is also stated:

Industry.	Average size engine in horse-power.	Horse-power per dollar's worth of product per hour.	Average number operatives per establishment.	Industry.	Average size engine in horse-power.	Horse-power per dollar's worth of product per hour.	Average number operatives per establishment.	Industry.	Average size engine in horse-power.	Horse-power per dollar's worth of product per hour.	Average number operatives per establishment.
Pig iron	115	2.75	71	Bleached and dye goods	42	0.29	17	Chairs	28	2.25	23
Cotton goods (see prints)	111	2.48	16	Printed paper	37	2.69	35	Bricks	28	1.00	13
Forged iron	104	2.22	121	Woolen goods	37	1.69	40	Ship-building	28	0.57	15
Nails	106	1.60	54	Railroad machinery	36	0.65	133	Sash, doors, and blinds	27	2.85	12
India rubber	90	1.29	108	Hats and caps	33	0.28	33	Hosiery	27	0.95	60
Sugar, refined cane	81	0.26	78	Drugs and chemicals	32	0.63	16	Soap and candles	25	0.52	7
Copper, milled and smelted	75	0.84	40	Sugar, raw cane	31	5.29	29	Agricultural implements	23	1.86	12
Carpets	67	0.51	56	Flour and grist	31	3.88	2	Cotton and wool machinery	23	1.33	26
Lead and zinc paint	61	1.42	26	Distilled liquors	31	1.13	7	Hardware	23	1.21	24
Cotton and woolen prints	55	0.54	212	Planed lumber	30	2.08	12	Stoves and castings	23	0.79	39
Milled quartz	47	2.06	10	Stone work	30	0.79	14	Cooperage	23	0.70	5
Worsted goods	47	1.09	127	Lead pipe	30	0.10	9	Engines and boilers	21	0.86	34
Sewing-machines	46	0.39	148	Sawed lumber	28	9.17	6	Coal-oil	21	0.47	11
Railroad cars	42	0.56	94								

In cases in which the material used is already a manufactured product the value of power in the whole manufacture is not indicated, but only that in the portion of the manufacture covered.

Cost of a horse-power.—The cost of a steam horse-power, like any other industrial value, varies considerably in different sections, as governed by the cost of transportation of fuel; at different times, as governed by the fluctuations of market values, and in respect to usage, as governed by the use of large or small, efficient or inefficient steam machinery. A fraction of the cost is always due to interest on investment, which may be assessed in various ways and with various allowances for the decadence of machinery.

In many classes of manufacture the employment of exhaust steam in sundry processes takes up the waste product of the boilers, so that economy of performance of the engines becomes of minor consequence. This is true of bleacheries, wool and straw-hat factories, dye-shops, tanneries, woolen mills, and other establishments using exhaust steam in the manufacturing processes. For example, at the Pontoosuc Woolen Mill, Pittsfield, Massachusetts, it is considered that, a large amount of steam being required in the dye-house in any event, they can get 100 horse-power for the mill by an additional use of coal to the amount of six-tenths of a pound per horse-power per hour. In northern factories, in which exhaust steam is used for heating, the exhaust of the engines does not usually furnish enough for the coldest weather, and live steam has to be used in part, so that the economy of the engine is lost in other requirements.

Of the cost of power in 1880 a few examples are given based on data as stated by various manufacturers interested.

In a factory in Worcester, Massachusetts, for a 60 horse-power engine the fuel used was mine pea, 270 tons, at $5 50=$1,485; the fireman and engineer was paid $500 salary; the cost of engines and boilers was $6,500, and the cost of investment and repairs was rated at 10 per cent. The cost of a horse-power per day was thus about 14½ cents.

In two factories at Hartford, Connecticut, the elements of cost per horse-power per day of ten hours were found to be—

	a.	*b.*
Interest on boilers and engines	$0 02	$0 02
Cost of attendance	04	02
Cost of fuel	10	07
Total	16	11

For a factory at Stamford the cost was, investment, 1 cent; attendance, $1\frac{1}{2}$ cents; fuel, $9\frac{1}{2}$ cents; total, 12 cents, and for another factory of similar power the cost was, investment, $1\frac{1}{2}$ cents; attendance, $2\frac{1}{2}$ cents; fuel, 7 cents; total, 11 cents. Such examples might be indefinitely multiplied, and with a market of fluctuating prices not a little depends upon the date at which the coal supply is obtained. In the west the cost of fuel is usually less, but as interest runs high, and the cost of machinery is often higher than in the east, the cost of steam-power does not appear very much reduced. An extreme case is that of an edge-tool factory close to a coal mine in a town in Pennsylvania. Here the fuel may be had for the taking, but the cost of investment is greater, as appears from the following estimate:

Interest on boilers and engines	$0 03
Cost of attendance	03
Repairs and contingencies	03
Cost of fuel (simply carting)	$01\frac{1}{2}$
Total	$10\frac{1}{2}$

The fuel was culm or duff—fine and dust coal which is sometimes burned like pine slabs to get its bulk out of the way. The steam machinery was inferior but costly. It is seen to have cost in two ways, in the first instance and for repairs.

Throttle-valve engines are commonly used in the west and south. For lumber-working, where the furnaces burn waste wood, and for cotton-seed-oil mills, in which the waste product serves as fuel, they are especially adapted. In every section the manufacturer, as is reasonable, tries to diminish the greatest element of cost, and alike consults his financial interests in getting a high-cost automatic engine in one case or a low-cost throttle-valve engine in the other.

Automatic engines first introduced as a superior product, covered by patent claims, of costly designs and with costly attachments, have heretofore been rated at much higher values for the power obtained than the plain slide-valve engines. The automatic engines of the drop cut-off type also ran at lower rotative speeds than the plain slide-valve engines, and with large ratios of expansion, required much larger cylinders for the same power. Upon the lapse of patent claims, and with the introduction of high speeds and positive-motion automatic engines of simpler designs, there is no question but that the sphere of this type of engine will be vastly enlarged, and that there will be a much greater saving in the aggregate cost of steam-power in the United States than we have already witnessed from this improvement of engines.

Portable engines.—In themselves portable and semi-portable engines, being usually of the plain slide- and throttle-valve type, present few features deserving of especial remark. The boilers used are of the locomotive and vertical tubular types in most cases. Sometimes horizontal return-flue or tubular boilers are used. For farm engines locomotive boilers are most common, the engine sometimes being placed on top and sometimes for easier access being bracketed to one side of the boiler, but whether the boiler used be horizontal or vertical the engine is almost invariably so placed that the main shaft shall be farthest removed from the fire-box of the boiler.

Boilers.—In the use of boilers, as of engines, we find similar degrees of economy attained by means of designs which exhibit great differences. In engines these differences are mainly confined to the details of governing mechanism, but in boilers they relate mainly to proportions, the efficiency of which varies greatly with the conditions of use, and as these conditions can not be known nor defined within a wide range, either by the builder or the user of the boiler, we find an innumerable variety of proportions. This variety is due in great measure to the methods of manufacture, which do not necessarily nor as an economic feature require uniformity of designs and patterns.

At the same time it can not be said that a greater uniformity is not desirable, and for the following reasons: In the first place, in the work of manufacture, uniformity of proportion makes more of what may be called "straight work", that is, work which is done over and over again until the boiler-maker is so habituated to it that he can do it just as it should be done every time. This is especially important in riveting, for with new forms of work continually taxing the ingenuity of the boiler-maker, there is more liability to discrepancy and to improper makeshifts, such as the use of the drift-pin. In the second place, a uniform design will be a good and safe design in order to commend itself to general use. While boiler explosions may not infrequently be due to sheer overtaxing of strength on account of too high pressure or of the violence of sudden fluctuations of pressure, they are in many cases caused by faults either of material or workmanship. It is also beyond question that the starting of cracks and flaws is often due to the treatment of the boiler by the steam user, to burning out from incrustations, to corrosion, and to unequal expansion. It is desirable that a boiler should not be so stayed or jointed that in getting up steam the parts should be strained by unequal expansion, or at least any more than is unavoidable. Uniformity would secure the best arrangement in this respect. In the third place, a greater degree of uniformity would furnish better facilities for inspection. The inspection of a boiler of peculiar design is a work of difficulty as well as of responsibility, and even after the boiler has been carefully examined, a conscientious inspector may not feel confident that it contains no lurking defect; but with a boiler of standard proportions, he can turn to the weakest points at once and feel reasonably confident that his work is thoroughly done.

Boilers of special design, such as the Lowe and the Babcock and Wilcox boilers, are likely to be made with greater uniformity of method as well as of product. The first Lowe boiler was put up in 1867 and has since had no repairs.

The farm portable boiler may be considered more liable to explosion than any other type. It is racked by motion. It is handled by men who are not engineers. Unlike the boilers of large factories, it does not have skilled care, nor is it so often guaranteed by local and insurance inspectors. Unlike marine and river-boat boilers, it is not subject to government inspection. And although these boilers are employed in large and increasing numbers, of portable boilers of all kinds, including boilers for the engines of threshers, hoisters, pile-drivers, and cotton-gins, there were reported only 13 explosions in 1880, out of a total of 170 explosions of all kinds of boilers. It is probable that in future years the rough usage of this class of boilers will find its outcome in a larger percentage of casualties, but some parties who build them largely have never had a boiler of their manufacture burst. Tanner & Co., of Richmond, Virginia, make this claim, though of course boilers however well made can not resist every exaction of time, corrosion, and ill usage. But the point which I wish to make is that these portables are built in lots and of uniform and simple designs without much flanging, thus securing more uniformly reliable workmanship.

In respect to unequal expansion, stays intended to strengthen a boiler have been so placed that they have operated under unequal expansion with a thrust or leverage tending to produce strains and cracks. Here again a uniform and approved practice would be a safeguard.

In the east, the return tubular boiler is the prevailing type for manufacturing purposes, but locomotive fire-box boilers are often used. In the west, return tubular boilers are used, but the return flue-boiler is the more common type, both of these types of boilers being fired externally. In some cases, notably in iron works, flue and plain cylinder boilers of great length (sometimes 50 or 60 feet long) are used. These are hung in supports, and the expansion of the top and bottom of the boilers being unequal, the central supports have in some cases been broken down, causing disastrous explosions, which rend the boilers asunder in the middle. Expansion is always more troublesome for great lengths. Thus, in laying steam-pipe, it is difficult to keep a long line of pipe steam-tight without some form of expansion joint.

In the west we find in practice no dividing line between flue and tubular boilers, the usage passing from cylindrical boilers to large flue boilers, and thence to boilers with 10-inch, 8-inch, 6-inch, 4-inch, and 3-inch flues or tubes. The flue boilers do not give as large a heating-surface as the tubular boilers, but by reason of better circulation their heating-surface may be more valuable for the same area, and they are more suitable for ordinary usage, impure water, and a low grade of fuel.

Heating-surface differs greatly in quality in the different parts of a boiler, and it is possible, under some forms of construction, that surfaces so estimated may actually become cooling-surfaces, or, at least, heating-surfaces whose good effect is almost nullified. In the journal "Locomotive" an ingenious, but simple, experiment is mentioned, showing the relative values of the heating-surfaces of tubes at different heights in the boiler. A small white pine stick is set up against a row of tube-holes, and becomes charred in bands opposite each tube; but when the stick is charred and burned through opposite the top tube it is scarcely scorched opposite the bottom tube, while the intermediate tubes illustrate, by charring the stick, a regular gradation of heat from top to bottom. The inference is that it is better to leave out the bottom return tubes, so as to give more water-volume for the direct heat of the furnace and combustion-chamber to act upon. Neither is it wise to impair the circulation by overcrowding the boiler with tubes.

In respect to the rating of boilers by so-called nominal powers, estimated in square feet of heating-surface, it may be said that such methods give a commercial name to an article, and that is all. The efficiency of a boiler once set may be altered by a change of fuel or method of stoking, by a forced draft, or even by a high wind, but we do not find boilers proportioned by any exact methods to meet particular requirements, because such requirements practically vary enough to upset the results of nice calculations. Boiler management may be considered to be yet in its infancy, so far as exact quantities are concerned, but a system of stoking which will secure some degree of uniformity, and a positive, quantitative, and mechanical regulation of the draft, are the conditions of the best results possible. If the steaming capacity of a boiler is known in pounds water per hour evaporated from 212°, under the ordinary pressure of 70 pounds, the steaming capacity sufficient to develop a horse-power varies from 15 to 40 or more pounds steam, according to the use and character of the engine. By forced draft, boilers may be made to make more steam, but not economically, unless the grate-surface be reduced. Air admitted above the grate helps to complete the combustion of the gases and of the particles of carbon in suspension (smoke), but it also dilutes the hot gases, and thus heat which would have gone into the steam may be carried out at the chimney.

Boilers for stationary and manufacturing purposes may be divided into two principal classes, viz, those with external and those with internal furnaces. The former, comprising nearly all return tubular, flue, and cylindrical boilers, are most generally used. They are obviously cheaper to build and involve less iron work than a boiler which contains the furnace within its shell. They are not always the most economical of fuel, but in employing them users are supposed to consult the considerations of first cost and expense of fuel, as one would do in choosing between an automatic cut-off and a slide-valve engine for a specified service. Some heat is expended in warming the exterior walls of masonry in external furnaces, but this loss is slight.

Boilers with internal furnaces are very largely used in New England and the east. These are for the most part of two types, locomotive-tubular and drop-return boilers. In these the furnace is within the water-space of the boiler, and the products of combustion are conducted back by tubes or flues directly through the boiler, and in the drop-return boilers find their way to the chimney through flues at a lower level leading toward the front end of the boiler and thence to the chimney. A form of drop-return boiler, highly approved for economy of fuel and largely used in New England, is the Lowe boiler. This has a combustion-chamber above the furnace, which communicates with it by two circular side passages. Thence the products of combustion pass through tubes to the back of the boiler and thence drop and pass under the boiler up by side flues and back over the top of the boiler to the chimney.

In some large factories the practice prevails of having ample boiler power or capacity and keeping each of the boilers "resting" some of the time under the idea that it conduces to their durability. However this may be, the attempt to get a large amount of steam by using a small boiler is certainly conducive neither to the durability of the boiler nor to economy of fuel. The economical rate of combustion is limited to about three-tenths pound of coal per hour per square foot of heating-surface. A first-rate boiler, evaporating 3 pounds of water per square foot of heating-surface per hour, will evaporate about $9\frac{1}{4}$ pounds water per pound coal. If it evaporate only 2 pounds of water per square foot of heating-surface per hour, it will evaporate from $9\frac{1}{2}$ to 10 pounds water per pound coal, and if it evaporate only 1 pound of water per square foot of heating-surface per hour it may evaporate as much as $10\frac{1}{2}$ pounds water per pound coal. These figures are for dry steam and ordinary conditions, viz, a feed temperature of 60°, steam pressure raised to 70 pounds per square inch, and coal used a good quality of anthracite containing about 90 per cent. combustible. If the boiler "prime", that is, cause water to pass off with the steam, a great weight of water per pound coal used may be made to pass through it, but it will be a weight of water and not of steam, and will be wasteful and injurious in its effect upon the steam machinery in which it is used. Thirteen pounds water per pound combustible is usually stated as the best attainable result with the most favorable conditions likely to be found outside of the laboratory. Very often not more than half this result is realized. In the direction of economy and durability there is no more notable movement than that of the introduction of feed water-heaters and purifiers, the use of which, in a great variety of designs, is largely on the increase.

Water-tube boilers.—Various forms of sectional and water-tube boilers have been introduced, designed to secure greater safety without sacrifice of economy. The most prominent among these is the Babcock and Wilcox boiler. In this there are a series of inclined water-tubes, sloping from the furnace front downward and backward, and connected with a mud-drum at the back and a horizontal steam- and water-drum at both ends, this drum being located above the tubes. The tubes are set "staggered" in end connections (in which they are fixed by an expander), while opposite each tube is an opening, closed by a hand-hole, plate-jointed, and rendered steam-tight by means of accurate milled surfaces. The boiler is largely used in the east, and is highly efficient. There is a continuous circulation of water descending from the upper drum through the back connection and passing up toward the furnace through the inclined tubes. In durability, ease of cleaning, freedom from priming, and rapid steaming, its good qualities have been demonstrated by some fifteen years of use. The space for combustion is ample, and the boiler is so hung from wrought-iron girders, independent of the brick-work, that there can be no serious strains due to unequal expansion.

Safety of boilers—Inspections.—The following statistics are furnished through the courtesy of the Hartford Steam Boiler Inspection and Insurance company. This company was chartered in 1866 and its object is not insurance primarily, but safety through inspection, the insurance being a guarantee of the work of inspection. For the entire United States the following explosions were reported during the years 1879 and 1880:

Kind of works and service.	1879.	1880.
Sawing, planing, and wood-working mills	41	47
Railroad locomotives and fire-engines	16	18
Steamboats, tugs, dredges, and dry-docks	13	15
Paper-, flouring-, pulp-, and grist-mills and elevators	10	19
Portables, hoisters, threshers, pile-drivers, and cotton-gins	9	13
Iron works, rolling-mills, furnaces, founderies, machine- and boiler-shops	10	13
Tanneries, belt and leather works, shoe and hat factories	....	2
Cotton, woolen, knitting, and other textile works	8	2
Distilleries, breweries, malt- and sugar-houses, soap and chemical works	8	10
Mines, oil refineries, and oil wells	4	8
Bleaching, digesting, dyeing, print-works, slaughtering, etc	4	3
Steam heating and drying. dwellings, schools, stores, and public buildings	....	2
Miscellaneous and mills not designated	9	18
Total	132	170

Between October 1, 1867, and January 1, 1880, records of 1,299 boiler explosions in the United States were obtained at the office of the inspection company, these including nearly all, and all of the more serious explosions in the country. They are classified as follows in respect to the character of service of boilers and the injury and destruction of life resulting from the explosions:

	Number boilers exploded.	Number persons killed.	Number persons injured.
Saw, planing, and wood-working mills	281	497	576
Steamboats, tugs, yachts, and steam-barges	186	956	816
Railroad locomotives	185	249	238
Iron works, furnaces, founderies, and machine-shops	92	147	324
Paper-, flouring-, and grist-mills, bleacheries, and print-works	92	96	122
Portable, hoisting, threshing, and pile-driving	66	143	137
Cotton-, woolen-, flax-, and other fabric-mills	55	72	131
Mines, quarries, oil-mills, and refineries	44	73	76
Heating and domestic boilers	29	10	33
Chemical, rendering, and slaughtering works	27	43	32
Distilleries, breweries, and sugar refineries	25	18	34
Miscellaneous (52 kinds of service)	217	201	93
Total	1,299	2,505	2,612

Up to the close of the year 1879 the company made (in a series of years) 92,850 thorough annual inspections, in which 31,183 dangerous defects were discovered, beside a much greater number of minor defects. But confining ourselves to such defects as were esteemed to involve peril to life and property, they were by number and kind as follows:

Fractures	5,079	Safety-valve overloaded	1,393
Cases of deposit of sediment	3,230	Cases of internal corrosion	1,124
Blistered plates	3,032	Water-gauges out of order	1,148
Burned plates	2,845	Furnaces out of shape	1,008
Pressure-gauges out of order	2,824	Blow-out apparatus out of order	802
Cases of incrustation and scale	2,756	Cases of internal grooving	444
Cases of external corrosion	2,665	Cases of deficiency of water	426
Broken braces and stays	2,171	Boilers without gauges	236

One thousand four hundred and sixty-three boilers were condemned altogether. The whole number of defects discovered, including those esteemed to involve no present danger, was 142,032.

Whether from a humane or from a merely commercial standpoint, the influence of an agency which has obviated so many perils must be highly esteemed.

INDEX TO MANUFACTURE OF ENGINES AND BOILERS.

REPORT

ON

MARINE ENGINES AND STEAM VESSELS

IN THE

UNITED STATES MERCHANT SERVICE,

BY

CHARLES H. FITCH, D. E.,
SPECIAL AGENT.

TABLE OF CONTENTS.

TABLE OF CONTENTS.

LIST OF ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

NEW HAVEN, CONNECTICUT, *October* 1, 1881.

SIR: In treating the subject of the Marine Engines and Steam Vessels of the United States Merchant Service I have, as a basis of comparison, classified the vessels in accordance with their registered tonnages. I have also made a cross-classification by geographical districts, viz, the Atlantic and Gulf service, the Pacific service, the Mississippi Valley service, and the Lake service, with several minor divisions of these classes. General statistical tables are presented of numbers of steam-vessels in active service, of the numbers of their engines and boilers, of the tonnages of the vessels, and the aggregate volumes of cylinders and boilers (excepting coil boilers, which are separately considered). The dimensions of steam vessels, engines, and boilers are in most cases those recorded by the United States steamboat inspectors.

The variety in dimensions and arrangement of boilers has rendered it impracticable to compute their aggregate heating surfaces, but the character and proportions of the boilers used in various sections and classes of service are so fully described as to permit of approximate estimates of these surfaces. The size of boiler as taken in these tables is the volume in cubic feet within the water-shell, including internal tubes, flues, and furnaces, but excluding external furnaces and fire-boxes. This "size of boilers" may be qualified by the detailed accounts of their dimensions and arrangement. Tables of averages are also given, which are believed to exhibit some interesting and instructive comparisons of practice. The average boiler-pressure allowed is stated for each district and class, and while there is no absolute measure of boiler capacity possible, the sizes as stated, taken in connection with the boiler pressures, will be found to convey as correct an idea of the steam-producing capacities as could well be furnished.

The manufacture of marine and river engines is involved both with the building of stationary engines and of steam vessels, but is more narrowly confined to manufacturing centers than the latter. The details of engine-building are considered in the report on stationary engines. Tables are herewith presented showing in detail how the various sections and places in the United States have contributed to the building up of the steam tonnage as inspected in 1879–1880.

The report then proceeds to consider, for the several grand geographical divisions, the details and character of engines and boilers used, and their relations to the arrangement, service, and speed of the steam vessels upon which they are employed. These details are freely illustrated, with the view of presenting a full and graphic record of the salient features of present practice.

Very respectfully,

CHARLES H. FITCH,
Special Agent.

Prof. WILLIAM P. TROWBRIDGE,
Chief Special Agent.

MARINE ENGINES AND STEAM VESSELS IN THE UNITED STATES MERCHANT SERVICE.

THE MARINE STEAM POWER OF THE UNITED STATES

TABLES OF AGGREGATES.

In preparing tables to exhibit the marine steam power of the United States, the steamers were first classified according to their registered tonnages, so as to bring steamers within certain limits of size in the same class, and thus to facilitate comparisons. The aggregates of these classes for the several inspection districts are given as follows, the boiler and cylinder volumes being calculated from data obtained from the records of the steamboat-inspection service through the courtesy of the supervising inspector-general, James A. Dumont.

The inspection districts are here designated not numerically, but so as to bring the geographical bearings of the statistics prominently before the mind of the reader. The first district embraces all waters and rivers of the United States west of the Rocky mountains, and is here designated as the Pacific district. The second district embraces the waters of the Atlantic coast, rivers and tributaries between the bay of Passamaquoddy and cape Charles. It may be designated as the North Atlantic district, and is here divided into two sections respectively, comprising the Atlantic seaboards of the New England and of the middle states. The third district embraces the waters of the Atlantic coast, rivers and tributaries between cape Charles and cape Sable. It is here designated as the south Atlantic district. The fourth district embraces the Mississippi river and tributaries, from the mouth of the Ohio river up to and including Keokuk, Iowa; the Illinois river below Peoria; the Missouri river up to and including Yankton, Dakota. It is here designated as the Saint Louis district. The fifth district embraces the upper Mississippi river and its tributaries above Keokuk, Iowa; the Red River of the North, and that part of the Missouri river and its tributaries above Yankton, Dakota. It is here designated as the upper Mississippi district. The sixth district embraces the Ohio river and tributaries up to and including Carrollton, Kentucky, and the Mississippi river and tributaries (below the Ohio) down to and including Greenville, Mississippi. It is here designated as the lower Ohio district. The seventh district, embracing the Ohio river and tributaries above Carrollton, Kentucky, is designated as the upper Ohio district. The eighth district embraces all the waters of the lakes north and west of lake Erie, their tributaries, and the upper portion of the Illinois river down to and including Peoria, Illinois. It is here designated as the Western lake district. The ninth district embraces all the waters of lakes Erie, Ontario, Champlain, Memphremagog, and George, with the river Saint Lawrence, and their tributaries, and the inland lakes of New York. It is here designated as the Eastern lake district. The tenth district embraces the coast and tributary waters of the gulf of Mexico between cape Sable and the mouth of the Rio Grande and the Mississippi river and tributaries to Greenville, Mississippi. It is here designated as the Gulf district.

	STEAMERS OF 1,000 TONS AND UPWARDS.						STEAMERS OF 500 TONS AND UPWARDS, UNDER 1,000 TONS.(a)					
	No. of steamers.	Tonnage.	No. of engines.	Volume, cylinders.	No. of boilers.	Volume, boilers.	No. of steamers.	Tonnage.	No. of engines.	Volume, cylinders.	No. of boilers.	Volume, boilers.
				Cubic feet.		*Cubic feet.*				*Cubic feet.*		*Cubic feet.*
The United States	307	480, 906. 17	407	41, 295. 26	770	1,030,464.43	396	277, 434. 00	535	27, 684. 40	770	651, 341. 75
The Pacific district	27	55, 348. 93	33	5, 464. 43	98	134, 153. 22	32	22, 352. 20	55	1, 350. 06	43	34, 023. 99
The North Atlantic (New England)	43	65, 005. 38	49	10, 791. 39	85	208, 982. 20	26	17, 915. 13	30	2, 364. 25	32	58, 323. 40
The North Atlantic (middle states)	91	160, 571. 93	105	14, 368. 82	222	386, 758. 93	133	91, 455. 47	136	14, 040. 08	168	278, 993. 62
The South Atlantic district	13	18, 965. 60	13	1, 533. 70	34	52, 639. 98	[illegible]	23, 410. 20	39	3, 157. 65	54	77, 646. 62
The Saint Louis district	10	13, 943. 67	20	679. 36	51	13, 986. 70	26	18, 414. 37	52	951. 95	98	21, 770. 49
The Upper Mississippi district							1	549. 21	2	19. 44	3	613. 71
The Lower Ohio district	3	3, 531. 73	6	165. 64	7	2, 127. 35	17	11, 671. 67	34	1, 009. 67	79	18, 606. 19
The Upper Ohio district	11	13, 634. 39	22	685. 60	58	13, 929. 78	42	28, 891. 16	84	1, 336. 66	161	41, 257. 99
The Western Lake district	25	31, 811. 27	34	1, 639. 76	40	48, 422. 28	38	26, 582. 49	43	1, 702. 47	52	52, 582. 28
The Eastern Lake district	58	79, 719. 42	86	3, 163. 71	78	92, 808. 99	30	24, 118. 65	34	882. 59	39	37, 381. 02
The Gulf district	26	38, 373. 85	39	2, 802. 85	97	76, 655. 00	17	12, 073. 45	26	870. 18	41	30, 243. 24

	STEAMERS OF 100 TONS AND UPWARDS, UNDER 500 TONS.(a)						STEAMERS OF 50 TONS AND UPWARDS, UNDER 100 TONS.(a)					
	No. of steamers.	Tonnage.	No. of engines.	Volume, cylinders.	No. of boilers.	Volume, boilers.	No. of steamers.	Tonnage.	No. of engines.	Volume, cylinders.	No. of boilers.	Volume, boilers.
				Cubic feet.		*Cubic feet.*				*Cubic feet.*		*Cubic feet.*
The United States	1, 362	332, 717. 43	2, 056	27, 434. 41	2, 375	914, 047. 41	808	59, 299. 62	1, 096	3, 557. 94	911	275, 445. 00
The Pacific district	109	26, 989. 02	192	1, 583. 24	158	55, 260. 65	48	3, 893. 63	83	218. 48	61	13, 312. 99
The North Atlantic (New England)	72	19, 232. 38	84	2, 012. 38	76	66, 249. 14	88	6, 529. 08	95	315. 18	88	38, 683. 22
The North Atlantic (middle states)	281	70, 202. 26	314	10, 159. 74	311	266, 002. 99	202	14, 227. 78	207	1, 314. 27	203	97, 278. 68
The South Atlantic district	119	32, 191. 76	146	2, 697. 06	230	86, 559. 67	77	5, 513. 40	95	323. 67	78	25, 553. 51
The Saint Louis district	90	25, 306. 81	159	1, 685. 47	239	48, 386. 94	35	2, 659. 68	58	183. 60	46	8, 424. 26
The Upper Mississippi district	73	13, 830. 99	144	745. 76	147	28, 450. 04	38	2, 863. 70	68	141. 96	49	7, 463. 97
The Lower Ohio district	86	21, 891. 09	168	1, 216. 91	210	41, 455. 01	62	4, 782. 34	108	156. 50	84	11, 504. 35
The Upper Ohio district	175	38, 607. 22	351	2, 914. 17	504	104, 134. 90	66	4, 649. 19	116	255. 92	99	15, 357. 75
The Western Lake district	141	37, 289. 25	167	1, 933. 63	166	102, 647. 21	89	6, 710. 03	120	279. 95	92	27, 711. 01
The Eastern Lake district	25	15, 068. 27	81	577. 19	78	37, 922. 48	37	2, 701. 89	38	130. 19	37	12, 402. 18
The Gulf district	141	32, 108. 38	250	1, 908. 86	256	96, 978. 38	66	4, 768. 90	108	238. 22	74	17, 753. 08

	STEAMERS OF 25 TONS AND UPWARDS, UNDER 50 TONS.(a)						STEAMERS OF LESS THAN 25 TONS.(a)					
	No. of steamers.	Tonnage.	No. of engines.	Volume, cylinders.	No. of boilers.	Volume, boilers.	No. of steamers.	Tonnage.	No. of engines.	Volume, cylinders.	No. of boilers.	Volume, boilers.
				Cubic feet.		*Cubic feet.*				*Cubic feet.*		*Cubic feet.*
The United States	831	30, 908. 18	995	1, 683. 14	841	189, 538. 48	1, 051	13, 942. 31	1, 179	673. 35	1, 057	97, 200. 39
The Pacific district	38	1, 484. 69	53	58. 10	39	6, 131. 97	47	506. 84	58	13. 79	48	2, 817. 77
The North Atlantic (New England)	93	3, 485. 09	102	169. 82	93	22, 900. 81	107	1, 352. 17	117	55. 05	107	9, 084. 32
The North Atlantic (middle states)	225	8, 319. 42	231	535. 96	225	60, 917. 27	251	3, 314. 95	265	191. 36	252	27, 364. 30
The South Atlantic district	100	3, 741. 70	108	226. 64	100	27, 084. 56	119	1, 542. 30	127	72. 17	119	11, 506. 49
The Saint Louis district	19	759. 00	27	29. 79	20	3, 036. 22	28	234. 69	34	7. 19	28	1, 330. 55
The Upper Mississippi district	25	899. 28	43	41. 07	26	3, 135. 79	18	314. 26	25	13. 01	19	1, 425. 96
The Lower Ohio district	34	1, 333. 02	50	35. 87	35	4, 435. 44	39	693. 47	51	33. 42	39	3, 424. 65
The Upper Ohio district	42	1, 600. 61	61	65. 74	44	5, 194. 65	33	520. 59	48	25. 05	34	2, 515. 86
The Western Lake district	149	5, 442. 45	186	322. 83	149	34, 881. 93	201	2, 920. 22	218	134. 74	202	19, 632. 93
The Eastern Lake district	54	1, 901. 52	66	92. 65	55	11, 372. 81	132	1, 640. 13	141	89. 27	132	12, 416. 64
The Gulf district	52	1, 941. 40	68	104. 67	55	10, 447. 03	77	902. 69	95	38. 30	77	5, 680. 83

RECAPITULATION—THE UNITED STATES. (a)

Steamers—	No. of steamers.	Tonnage.	No. of engines.	Volume, cylinders.	No. of boilers.	Volume, boilers.
				Cubic feet.		*Cubic feet.*
The United States	4, 755	1, 195, 207. 71	6, 268	102, 328. 50	6, 724	3, 158, 037. 46
Over 1,000 tons	307	480, 906. 17	407	41, 295. 26	770	1, 030, 464. 43
500 to 1,000 tons	396	277, 434. 00	535	27, 684. 40	770	651, 341. 75
100 to 500 tons	1, 362	332, 717. 43	2, 056	27, 434. 41	2, 375	914, 047. 41
50 to 100 tons	808	59, 299. 62	1, 096	3, 557. 94	911	275, 445, 00
25 to 50 tons	831	30, 908. 18	995	1, 683. 14	841	189, 538. 48
Under 25 tons	1, 051	13, 942. 31	1, 179	673. 35	1, 057	97, 200. 39

a These aggregates do not include a small number of steamers having coil and other special types of boiler.

TABLES OF AVERAGES.

The following tables of averages are presented for convenience in comparison of the several classes of vessels. In the tables, a compound engine with high- and low-pressure cylinders is rated as one engine, but two high-pressure cylinders with connecting mechanism are rated as two engines. The tables exhibit conspicuously certain general tendencies, such, for example, as the increase of boiler volume for the same tonnage and cylinder capacity as we proceed from the larger to the smaller vessels. The extremes of cylinder volume and boiler pressure are exhibited by the horizontal engines of the western river boats on one side and the beam-engines of eastern river and sound boats on the other. These matters will be made the subject of further remark.

	AVERAGES FOR STEAMERS OF 1,000 TONS AND UPWARDS.							AVERAGES FOR STEAMERS OF 500 TONS AND UPWARDS, UNDER 1,000 TONS.						
	Average tonnage of steamers.	Cylinder volume per 100 tons.	Boiler volume per 100 tons.	Ratio of boiler to cylinder volume.	Average boiler pressure allowed to square inch.	Cylinder volume per single engine.	Boiler volume per single boiler.	Average tonnage of steamers.	Cylinder volume per 100 tons.	Boiler volume per 100 tons.	Ratio of boiler to cylinder volume.	Average boiler pressure allowed to square inch.	Cylinder volume per single engine.	Boiler volume per single boiler.
		Cu. ft.	Cu. ft.		Lbs.	Cu. ft.	Cu. ft.		Cu. ft.	Cu. ft.		Lbs.	Cu. ft.	Cu. ft.
The Pacific district	2,049.96	9.87	242.38	24.56	63	165.59	1,368.91	698.51	6.04	152.21	25.20	95	24.55	791.25
The North Atlantic district (New England)	1,511.75	16.60	321.48	19.36	33	220.23	2,199.79	689.04	13.19	325.55	24.68	35	78.81	1,822.61
The North Atlantic district (middle states)	1,764.52	8.95	240.86	26.92	40	136.84	1,742.15	688.39	15.35	304.95	19.87	34	103.24	1,660.08
The South Atlantic district	1,458.89	8.08	277.56	34.35	48	117.98	1,842.35	688.54	13.49	331.67	24.59	38	80.96	1,437.90
The Saint Louis district	1,394.37	4.87	100.31	20.18	138	33.97	274.25	708.24	5.17	118.23	22.87	141	18.31	222.15
The Upper Mississippi district	....	....	....	....	....	....	....	549.21	3.54	111.74	31.56	131	9.72	204.57
The Lower Ohio district	1,177.24	4.68	60.24	12.87	141	27.61	303.91	686.57	8.65	159.41	18.43	152	29.69	235.52
The Upper Ohio district	1,239.49	5.93	102.17	20.31	154	31.16	240.17	687.88	4.62	142.08	30.75	152	15.91	250.05
The Western Lake district	1,272.45	5.16	152.22	29.50	69	48.23	1,210.55	699.54	6.41	197.81	30.86	63	39.59	1,011.19
The Eastern Lake district	1,374.47	3.97	116.42	29.33	72	36.79	1,189.86	803.95	3.66	154.99	42.35	67	25.96	958.48
The Gulf district	1,475.92	7.30	199.76	27.36	93	71.86	790.26	710.20	7.21	250.49	34.74	98	33.47	737.64

	AVERAGES FOR STEAMERS OF 100 TONS AND UPWARDS, UNDER 500 TONS.							AVERAGES FOR STEAMERS OF 50 TONS AND UPWARDS, UNDER 100 TONS.						
	Average tonnage of steamers.	Cylinder volume per 100 tons.	Boiler volume per 100 tons.	Ratio of boiler to cylinder volume.	Average boiler pressure allowed to square inch.	Cylinder volume per single engine.	Boiler volume per single boiler.	Average tonnage of steamers.	Cylinder volume per 100 tons.	Boiler volume per 100 tons.	Ratio of boiler to cylinder volume.	Average boiler pressure allowed to square inch.	Cylinder volume per single engine.	Boiler volume per single boiler.
		Cu. ft.	Cu. ft.		Lbs.	Cu. ft.	Cu. ft.		Cu. ft.	Cu. ft.		Lbs.	Cu. ft.	Cu. ft.
The Pacific district	247.61	5.87	204.75	34.91	95	8.24	349.75	81.12	5.61	341.92	76.75	92	2.63	201.85
The North Atlantic district (New England)	267.12	10.46	344.46	32.93	56	23.96	871.69	74.19	4.83	592.47	132.40	78	3.32	439.58
The North Atlantic district (middle states)	249.83	14.47	378.99	26.19	52	32.35	855.31	70.43	9.24	683.72	75.70	69	6.33	479.20
The South Atlantic district	270.51	8.38	268.88	32.08	52	18.47	376.34	71.61	5.87	463.44	96.07	66	3.41	327.61
The Saint Louis district	281.18	6.66	191.20	28.71	136	10.60	202.46	75.99	6.90	316.74	58.59	121	3.16	183.14
The Upper Mississippi district	189.46	5.39	205.70	38.16	136	5.18	193.54	75.36	4.96	253.66	73.23	123	2.08	152.33
The Lower Ohio district	231.27	5.56	189.37	34.06	143	7.24	197.40	77.13	3.27	240.56	94.45	124	1.45	136.86
The Upper Ohio district	220.51	7.55	269.73	35.72	148	8.30	206.61	70.44	5.50	330.33	70.19	127	2.21	155.13
The Western Lake district	264.46	5.18	275.27	53.14	77	11.58	618.35	75.39	4.17	412.98	129.28	89	2.33	301.21
The Eastern Lake district	200.91	3.83	251.67	65.71	77	7.13	486.18	73.02	4.82	459.02	97.72	87	3.43	335.19
The Gulf district	227.72	5.94	239.75	40.35	113	7.63	300.69	72.25	5.00	372.27	108.55	100	2.21	239.91

	AVERAGES FOR STEAMERS OF 25 TONS AND UPWARDS, UNDER 50 TONS.							AVERAGES FOR STEAMERS OF LESS THAN 25 TONS.						
	Average tonnage of steamers.	Cylinder volume per 100 tons.	Boiler volume per 100 tons.	Ratio of boiler to cylinder volume.	Average boiler pressure allowed to square inch.	Cylinder volume per single engine.	Boiler volume per single boiler.	Average tonnage of steamers.	Cylinder volume per 100 tons.	Boiler volume per 100 tons.	Ratio of boiler to cylinder volume.	Average boiler pressure allowed to square inch.	Cylinder volume per single engine.	Boiler volume per single boiler.
		Cu. ft.	Cu. ft.		Lbs.	Cu. ft.	Cu. ft.		Cu. ft.	Cu. ft.		Lbs.	Cu. ft.	Cu. ft.
The Pacific district	39.07	3.91	413.02	142.93	93	1.10	157.23	10.78	2.72	553.97	244.58	103	0.24	58.70
The North Atlantic district (New England)	37.47	4.84	653.72	152.94	79	1.61	246.24	12.64	4.07	671.83	180.63	94	0.47	84.90
The North Atlantic district (middle states)	36.97	6.44	732.23	113.70	76	2.32	270.74	13.21	5.77	825.48	150.82	84	0.72	108.59
The South Atlantic district	37.42	6.06	723.86	128.98	69	2.10	270.85	12.96	4.68	746.06	169.63	79	0.57	96.69
The Saint Louis district	39.94	3.09	400.03	138.01	105	1.10	151.81	8.38	3.06	571.20	226.29	106	0.21	47.52
The Upper Mississippi district	35.97	4.57	348.70	126.96	120	0.95	120.61	17.46	4.14	453.75	144.32	115	0.52	75.05
The Lower Ohio district	39.21	2.69	332.73	178.49	116	0.71	126.73	17.78	4.82	493.84	135.09	111	0.65	87.81
The Upper Ohio district	38.11	4.11	324.54	109.31	116	1.08	118.06	16.27	4.81	483.27	142.25	118	0.52	73.97
The Western Lake district	36.52	5.93	640.92	134.54	91	1.74	234.11	14.53	4.62	672.31	156.76	92	0.62	97.19
The Eastern Lake district	35.21	4.87	598.09	147.70	98	1.40	206.78	12.43	5.44	757.05	149.32	99	0.63	94.07
The Gulf district	37.33	5.39	538.12	123.41	92	1.54	189.95	11.72	4.24	629.32	184.42	81	0.40	73.77

AVERAGES—THE UNITED STATES.(a)

Steamers.	Average tonnage of steamers.	Cylinder volume per 100 tons.	Boiler volume per 100 tons.	Ratio of boiler to cylinder volume.	Average boiler pressure allowed to square inch.	Cylinder volume per single engine.	Volume boiler per single boiler.
		Cu. ft.	*Cu. ft.*		*Lbs.*	*Cu. ft.*	*Cu. ft.*
Over 1,000 tons	1,566.47	8.58	214.27	24.96	65	101.43	1,339.57
500 to 1,000 tons	700.59	9.98	234.77	23.53	73	51.74	845.90
100 to 500 tons	214.28	8.25	274.72	33.30	94	13.34	384.86
50 to 100 tons	73.39	6.00	464.49	77.41	90	3.25	202.35
25 to 50 tons	37.19	5.32	612.94	115.21	87	1.65	225.37
Under 25 tons	13.27	4.83	697.18	144.34	92	0.58	91.96
All sizes	251.36	8.56	264.23	30.87	88	16.32	469.66

a These averages do not include a small number of steamers having coil and other special types of boiler.

STEAMSHIP BUILDING.

Within the past decade there has been a falling off in ship-building, but not in the building of steamships and other steam vessels, and the ratio of number of steam to number of sailing vessels built is now greater than ever before.

A small diagram has been prepared (Fig. 1) which exhibits the progress of the country for the past forty years

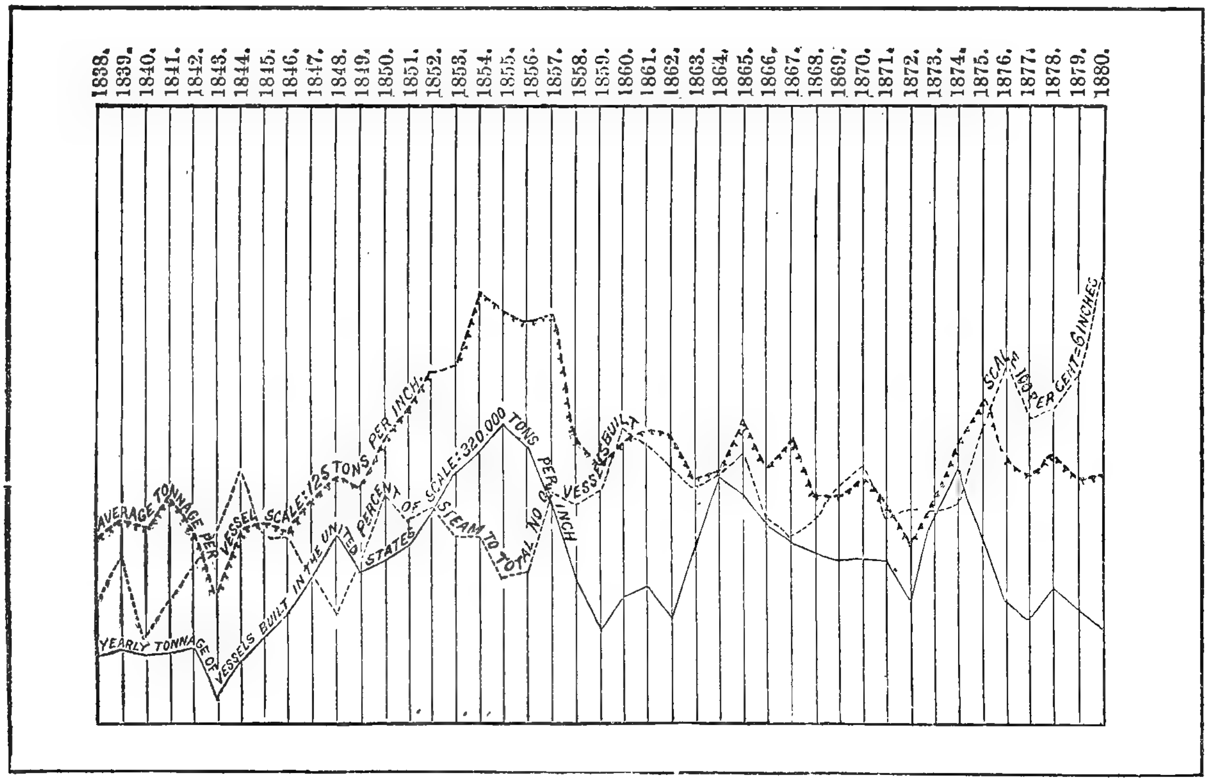


FIG. 1.

in this respect. The diagram may be considered an epitomized history in itself, but a few notes may be of value in recalling to the mind of the reader some of the industrial conditions prevailing at the several dates.

From 1838 to 1843 we find the ship-building interest small and diminishing, the average size of vessels becoming smaller, with an increased percentage of steamers, all being wooden vessels. In this period the revenues of the government were such that it was a question what should be done with the surplus. Iron steamships were fairly introduced in England, and the Cunard line was started.

From 1843 to 1854 we had a great growth in ship-building in this country, attending a growth of commerce. There was a marked increase in the national debt and in the revenue from duties, while the average percentage of tariff on dutiable imports fell off from about 35 to about 25 per cent. The relative proportion of steamers built declined, showing the ship-building growth to be mainly in sailing vessels. All the ocean-going steamers were wooden vessels. The Collins trans-Atlantic line was started. The period 1843–1854 was also of great commercial

activity in England. Many iron steamers were built, and by 1845 marine tubular boilers had come into general use. In this country from 1854 to 1857 vessels of a larger average size were built than at any later period, but these large craft were mainly wooden sailing vessels. It may be noted that in 1846 the Mexican war began, while in 1849 the discovery of gold in California attracted the adventurous.

From 1854 to 1862 was a period of decadence, due to the fact that the wooden ships of American build were being supplanted in the carrying trade by iron steamers of foreign build. In 1860 52 wooden side-wheel steamers were the only ocean-going steamers of the United States, although large iron steamers had been built in this country over fifteen years previous.

The civil war now gave an impetus to the building of vessels, but they were still for the most part of wood, and only about one-fifth of them were steamers. Another period of decadence followed till 1872. Meanwhile from 1861 to 1864 alone England doubled her ship-building, which was nearly all in iron steamers. Other industrial enterprises flourished in this country; the "Great Eastern" brought us the Atlantic cable in 1866, and the Union Pacific railroad was finished in 1869, but ship-building continued to decline.

The year 1872 appears to have been a temporary turning point in ship-building, coincident with a period of business stagnation and low wages in the United States. In 1874 the tonnage built approached that of 1855, being exceeded only in three years—1854, 1855, and 1856—and a much larger proportion of the vessels were steamers. But with the return of prosperity in the country labor appears to have been drawn into other callings and ship-building rapidly fell away. In 1871 a free-ship bill was defeated in Congress. The law passed in 1872 giving ship-builders the right to import free of duty materials to be used in ships for the foreign trade was practically inoperative. Nevertheless, the building of large iron steamships now began to be prosecuted with some success, and for the next seven years these were built, in four iron ship-yards on the Delaware, at an average rate of 11 large sea-going iron steamships a year, with an average tonnage of about 2,000 tons each. But the bulk of the steam tonnage built consisted of small tugs and river boats; and from 1874 to 1880 there was a further decline in ship-building, slightly checked only in 1878, in which year it may be remarked that an American line to Brazil was started with three steamers, the largest being of 3,548 tons burden. In this last period there has been a decided increase in the ratio by number of steam to sailing vessels.

We may say roundly that the ratio of number of steamers to total number of vessels built was, in 1840, about one-twelfth; in 1850, about one-fifth; in 1860, about one-fourth; in 1870, about two-ninths; in 1880, about three-eighths.

The number of steamers built, by years, is as follows, since 1840:

Years.	Number.	Years.	Number.	Years.	Number.	Years.	Number.
Total ten years	1,685	Total ten years	2,443	Total ten years	3,054	Total ten years	3,343
1841	78	1851	233	1861	264	1871	302
1842	137	1852	259	1862	183	1872	292
1843	79	1853	271	1863	367	1873	402
1844	163	1854	281	1864	498	1874	404
1845	163	1855	253	1865	411	1875	323
1846	225	1856	221	1866	348	1876	338
1847	198	1857	263	1867	180	1877	265
1848	175	1858	226	1868	236	1878	334
1849	208	1859	172	1869	277	1879	335
1850	259	1860	264	1870	290	1880	348

The aggregates, taken by decades, show a general increase in steamship building, but this no more than supplies the demand for coasting and river steamers. Indeed, the building of large steamers must within the next few years be considerably increased in order to supply the domestic demand.(*a*) The average life of a steamboat may be taken at from sixteen to twenty years, and many of the large steamers are old, especially the large wooden coasting vessels, not a few of these having been built at places in which the building of large ocean steamers may be said to have become almost a lost art. Thus of 129 large sea-going steamers 20 built in New York and Brooklyn average about fifteen years old, 4 of foreign build average nineteen years old, and 12 built in Connecticut average nearly fifteen years old. Such old wooden steamers are being replaced by iron steamers, which are built mainly at Chester, Pennsylvania; Wilmington, Delaware, and Philadelphia, Pennsylvania. Of the steam tonnage inspected in 1879 the following tables have been prepared, which show in what proportions the several states and places have contributed to the building up of the steam tonnage. The tables are deficient by about 2 per cent. of the whole number of steamers, these being mostly small craft, of which the data were not obtainable.

a In a recent issue of the *Nautical Gazette* the demand upon American ship-builders for steam tonnage is stated to be greater than it has been for ten years past.

STEAM VESSELS OF THE UNITED STATES.

NOTE.—This table is incomplete by the necessary omission of a very small percentage of steamers of unknown build and of small steamers of unmeasured tonnage. There are also 17 steamers of foreign build: 4 ocean passenger, 3,027.07 tons; 2 inland passenger, 229.17 tons; 4 ferry, 446 tons; 2 towing, 328.96 tons; 3 freight steamers, 1,808.94 tons, and 2 steam yachts, 16.77 tons.

Where built.	OCEAN PASSENGER STEAMERS.		INLAND PASSENGER STEAMERS.		FERRY BOATS.		TOWING BOATS.		FREIGHT STEAMERS.		OTHER STEAMERS.	
	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.
The United States	129	188, 410. 29	1, 511	457, 485. 39	392	118. 380. 65	1, 251	103, 238. 79	390	197, 974. 79	591	29, 828. 60
Alabama	1	508. 05	4	606. 32	1	17. 00	8	272. 81	[illegible]	576. 62	1	3. 00
Alaska			1	255. 44								
Arkansas			8	813. 16	[illegible]	161. 20	1	12. 40	1	29. 46	1	70. 83
California	6	3, 006. 70	56	9, 584. 34	29	21, 803. 21	28	1, 755. 40	23	3, 248. 48		
Connecticut	12	11, 076. 77	27	5, 782. 82	7	637. 37	[illegible]	791. 31	11	4, 909. 69	20	1, 380. 81
Dakota			1	217. 77	1	44. 91						
Delaware	23	32, 897. 27	51	24, 478. 13	16	6, 757. 70	24	1, 524. 36	21	20, 156. 82	16	2, 200. 31
District of Columbia			3	386. 14							2	70. 13
Florida	1	1, 073. 95	13	1, 358. 96			7	374. 25	[illegible]	171. 65	1	19. 58
Georgia			8	1, 201. 12							1	11. 59
Illinois			19	4, 525. 78	33	4, 064. 93	50	3, 274. 55	8	715. 05	34	2, 361. 61
Indiana			131	52, 636. 20	40	6, 562. 60	26	1, 960. 27	9	974. 26	3	74. 75
Iowa			18	1, 413. 82	10	664. 79	21	1, 651. 26	1	4. 00		
Kansas					4	446. 00						
Kentucky			23	4, 985. 66	7	758. 62	8	606. 17	3	363. 09		
Louisiana			8	1, 195. 40	1	16. 17	12	664. 39	3	234. 48	25	298. 93
Maine			25	3, 326. 34	5	902. 21	8	421. 10	4	1, 088. 45	44	2, 900. 81
Maryland	[illegible]	723. 63	46	12, 046. 37	3	675. 52	15	1, 020. 47	3	250. 90	4	100. 14
Massachusetts	[illegible]	7, 718. 74	25	2, 442. 11	9	2, 884. 66	12	751. 10	8	723. 81	26	1, 044. 05
Michigan	1	387. 92	49	18, 421. 53	4	636. 13	90	6, 278. 59	73	38, 140. 16	50	959. 89
Minnesota			15	1, 480. 44	1	63. 76	9	1, 003. 07			1	7. 02
Mississippi			7	645. 03			2	53. 56	5	218. 62	2	25. 22
Missouri			19	9, 093. 44	13	1, 500. 59	8	557. 20	8	459. 25	2	354. 65
New Hampshire			4	216. 21								
New Jersey	4	2, 259. 67	74	17, 936. 86	20	9, 305. 51	68	4, 916. 77	10	3, 380. 28	39	2, 404. 08
New York	25	40, 891. 78	284	122, 025. 85	109	49, 893. 48	300	17, 016. 80	68	51, 830. 86	169	7, 527. 00
North Carolina			15	1, 352. 29			3	26. 00	1	91. 42		
Ohio			158	70, 585. 34	27	2, 131. 08	79	9, 382. 11	46	42, 625. 30	35	1, 390. 37
Oregon			63	20, 824. 64	7	1, 499. 26	5	182. 25	4	297. 94		
Pennsylvania	47	85, 695. 49	182	38, 460. 76	22	5, 330. 41	353	43, 334. 23	39	24, 344. 91	84	5, 999. 81
Rhode Island			4	143. 59			1	8. 39			12	292. 18
South Carolina			6	1, 251. 65			[illegible]	44. 47			1	13. 19
Tennessee			19	2, 003. 81	1	314. 84	4	47. 71	2	72. 37		
Texas			1	185. 95			5	157. 93	1	65. 83		
Vermont			2	1, 399. 06								
Virginia	1	1, 437. 96	25	3, 492. 99	3	445. 94	17	379. 32	[illegible]	527. 37	[illegible]	17. 70
Washington Territory	1	732. 36	31	3, 279. 88	1	181. 81	1	110. 59	[illegible]	63. 01		
West Virginia			27	4, 683. 80	10	532. 19	14	2, 010. 21	2	78. 49	1	3. 00
Wisconsin			59	12, 746. 39	5	148. 76	61	2, 649. 75	18	2, 332. 22	15	297. 95

Steam vessels of the United States—Continued.

Where built.	Ocean passenger steamers.		Inland passenger steamers.		Ferry boats.		Towing boats.		Freight steamers.		Other steamers.	
	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.
ALABAMA	1	508.05	4	606.32	1	17.00	8	272.81	5	576.62	1	3.00
Cheney's Landing									1	73.00		
Fish River							1	25.43				
Gadsden			1	57.65			2	57.65				
Mobile	1	508.05	2	357.49			5	189.73	2	361.47		
Portland									1	112.00		
Selma					1	17.00			1	30.15		
Stockton											1	3.00
Whitesburg			1	191.18								
ALASKA, Sitka			1	255.44								
ARKANSAS			8	813.16	3	161.20	1	12.40	1	29.46	1	70.83
Arkansas Post											1	70.83
Dardanelles					1	72.45						
Fort Smith			1	89.74								
Helena			1	130.25			1	12.40				
Jacksonport			1	115.35								
Little Rock			3	277.18								
Madison									1	29.46		
Pine Bluff			1	76.09	1	24.93						
Spadra			1	124.55								
Van Buren					1	63.82						
CALIFORNIA	6	3,006.70	56	9,584.34	29	21,803.21	28	1,755.40	23	3,248.48		
Eureka	1	388.92	1	90.00			2	138.82				
Fair Haven					1	104.07						
Humboldt							1	133.18				
Lapham's Landing			1	68.14								
Martinez					1	102.00						
Marysville									1	168.03		
Oakland					2	5,116.12						
Roland's Landing							1	10.00				
Sacramento			1	176.02					2	302.99		
San Francisco	5	2,617.78	37	6,321.70	25	16,481.02	18	1,261.67	16	2,256.04		
Stockton			12	2,630.61			5	205.63	4	521.42		
Tahoe City			1	28.00								
Union City			1	96.06								
Vallejo			1	21.79								
Washington							1	6.10				
Wilmington			1	102.02								
CONNECTICUT	12	11,076.77	27	5,782.82	7	637.37	8	791.31	11	4,909.69	20	1,380.81
East Haddam	2	2,068.99	3	1,345.35	1	14.40			1	132.08		
Glastonbury					1	12.68						
Guilford											1	19.17
Hartford					1	104.32	1	86.37			1	19.27
Middletown			1	293.24			1	35.93				
Mystic	6	5,949.42	9	2,223.64	1	127.15	3	297.29	7	3,604.38	9	791.74
New Haven			4	531.85					1	417.94		
New London			2	54.95			1	23.20			2	157.42
Noank			5	1,212.83							5	325.03
Norwich	2	963.73					1	296.19	1	566.83		
Portland	2	2,094.63			1	329.23			1	188.46		
South Norwalk			2	51.88			1	52.33			2	68.18
Suffield			1	68.98	2	49.59						
DAKOTA			1	217.77	1	44.91						
Fargo			1	217.77								
Yankton					1	44.91						
DELAWARE	23	32,897.27	51	24,478.13	16	6,757.70	24	1,524.36	21	20,156.82	16	2,200.31
Concord											1	14.14
Fennimore									1	131.41		
New Castle							1	173.50				
Wilmington	23	32,897.27	51	24,478.13	16	6,757.70	23	1,350.86	20	20,025.41	15	2,186.17

Steam vessels of the United States—Continued.

Where built.	Ocean passenger steamers.		Inland passenger steamers.		Ferry boats.		Towing boats.		Freight steamers.		Other steamers.	
	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.
DISTRICT OF COLUMBIA			3	386.14							2	70.13
Georgetown			1	26.99								
Washington			2	359.15							2	70.13
FLORIDA	1	1,073.95	13	1,358.96			7	374.25	2	171.65	1	19.58
Cedar Keys							1	48.80	1	139.65		
Jacksonville			7	996.40			1	11.53				
Leesburg			1	76.48								
Mayport Mills											1	19.58
Milton							1	25.42				
Palatka			5	286.08								
Pensacola	1	1,073.95					2	158.85				
Perdido							1	85.48				
Sinnabel's island									1	32.00		
Wilmington							1	44.17				
GEORGIA			8	1,201.12							1	11.59
Columbus			2	412.77								
Rome			2	458.00								
Saint Mary's			2	246.15								
Savannah			2	84.20							1	11.59
ILLINOIS			19	4,525.78	33	4,064.93	50	3,274.55	8	715.05	34	2,361.61
Cairo			1	7.80			2	95.82				
Carmi									2	111.89		
Chicago			3	542.37			27	951.94	4	196.86	21	1,089.95
Galena							1	38.79				
Golconda							1	23.01				
Grafton			1	132.74	8	614.33	2	323.63	1	180.44		
Grand Tower					1	92.26	1	83.36				
Grayville					1	23.31						
Griggsville Landing					2	48.44						
Havana			1	3.00								
Joliet					1	93.09						
Keithsburg			1	49.21								
Lockport											10	1,069.64
Meredosia			1	4.83	1	24.64						
Metropolis City			4	2,086.07	9	1,723.99	9	1,296.29				
Mound City			3	1,085.26	5	1,161.72			1	225.86		
Peoria			2	8.80	1	43.40					2	111.81
Peru							1	71.04			1	90.21
Pleasant Valley					1	23.74						
Port Byron					1	33.79						
Quincy			1	449.47	1	165.07	1	7.61				
Rock Island					1	17.15	3	302.83				
Saint Bernard							1	18.71				
Savannah							1	61.52				
Warsaw			1	156.23								
INDIANA			131	52,636.37	40	6,562.60	26	1,960.27	9	974.26	3	74.75
Aurora			2	53.12								
Bridgeport					1	49.60						
Evansville			12	2,224.73	5	183.22	9	527.30	1	78.15		
Hazelton							1	22.79	1	58.21		
Jeffersonville			80	39,365.59	10	2,173.31	4	370.04	3	407.92	1	5.00
La Fayette			2	86.58			1	60.34	2	97.44	1	42.20
Logansport							1	66.11				
Madison			26	9,821.84	11	1,940.39	6	769.24	1	83.83	1	27.55
Michigan City									1	248.71		
Mount Carmel							1	10.58				
Mount Vernon					2	44.16						
New Albany			4	664.38	10	2,151.92	1	54.11				
Shoals			1	90.23			1	58.60				
Terre Haute			2	143.83								
Vevay			1	96.81	1	20.00						
Vincennes			1	89.26								
Washington							1	21.16				

Steam vessels of the United States—Continued.

Where built.	Ocean passenger steamers.		Inland passenger steamers.		Ferry boats.		Towing boats.		Freight steamers.		Other steamers.	
	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.
IOWA			18	1,413.82	10	664.79	21	1,651.26	1	4.00		
Bellevue			3	105.34			1	52.74				
Burlington			4	201.56			2	84.78				
Clayton			1	32.00								
Clinton			1	176.73	1	155.97	4	419.95	1	4.00		
Davenport			1	14.04			1	2.16				
Dubuque			3	658.77	3	154.37	3	100.59				
Gilbert Town					1	18.00						
Le Claire			1	168.38	1	65.44	6	555.35				
Lyons			3	49.87	1	142.72	1	4.15				
Maquoketa							2	102.39				
Montrose					1	54.50						
Muscatine			1	7.13	1	61.79						
Pieville					1	12.00						
Saint Claire							1	239.15				
KANSAS					4	446.00						
Leavenworth					3	388.93						
Wyandotte					1	57.07						
KENTUCKY			23	4,985.66	7	758.62	8	606.17	3	363.09		
Ashland			2	78.30								
Carrsville			1	20.20								
Caseyville			2	130.84								
Catlettsburg			2	161.51								
Constance					1	21.25						
Covington			2	100.87								
Hudson					2	38.13						
Louisville			8	3,743.19	3	584.58	3	294.49	2	217.36		
Newport							1	4.80				
Owensborough			1	37.36								
Paducah			4	678.93	1	114.66	1	140.51	1	145.73		
Proctor			1	34.46								
Rockport							1	13.39				
Westonburgh							1	55.80				
West Point							1	97.18				
LOUISIANA			8	1,195.40	1	16.17	12	664.39	3	234.48	25	298.93
Alexandria					1	16.17						
Algiers											1	18.08
Baton Rouge							1	34.94				
Bayou Boeuf									2	75.40		
Berwick							1	52.68			2	24.39
Breaux's Bridge											1	28.08
Franklin							2	162.81	1	159.08		
Gosport			1	69.35								
Houma											2	37.86
Jefferson											1	37.65
Lake Charles							2	69.00				
Madisonville			3	511.53								
Mountain Bayou			1	42.35								
New Iberia											1	8.53
New Orleans			3	572.17			5	288.11			13	111.48
Plaquemine							1	56.85			2	23.75
Shreveport											1	7.89
Trinity											1	11.22
MAINE			25	3,326.34	5	902.21	8	421.10	4	1,088.45	44	2,900.81
Bangor							1	190.49				
Bath			4	527.31	4	886.24	1	48.25	1	420.50	10	529.02
Belfast			1	41.07								
Booth Bay											3	223.38
Brewer			2	207.93								
Bristol											4	250.14
Bucksport					1	15.97						
Calais			1	4.00			1	32.18				

Steam vessels of the United States—Continued.

Where built.	OCEAN PASSENGER STEAMERS.		INLAND PASSENGER STEAMERS.		FERRY BOATS.		TOWING BOATS.		FREIGHT STEAMERS.		OTHER STEAMERS.	
	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.
MAINE—Continued.												
Cape Elizabeth			2	58.93								
Cherryfield							1	8.72				
Damariscotta											4	323.47
East Deering											11	738.14
Hogdon's Mills											3	231.60
Kennebunk			2	730.42							3	228.29
Millbridge			1	102.57								
Portland			8	1,510.82			2	80.07	2	548.38		
Richmond			1	14.95								
Rockland			1	37.80								
Round Pond											1	52.53
Saco			1	72.04					1	119.57		
South Bristol											5	324.24
Thomaston							1	11.75				
Upton			1	18.50								
Wicasset							1	49.64				
MARYLAND	2	723.63	46	12,046.37	3	675.52	15	1,020.47	3	250.90	4	100.14
Annapolis					1	45.04						
Baltimore	1	493.00	44	11,676.27	2	630.48	14	1,001.03			3	39.94
Cambridge							1	19.44				
Crumpton			1	326.52								
Cumberland									2	120.00	1	60.20
Havre de Grace	1	230.63							1	130.90		
Solomon's Island			1	43.58								
MASSACHUSETTS	5	7,718.74	25	2,442.11	9	2,884.66	12	751.10	8	723.81	26	1,044.05
Agawam			1	95.32								
Boston	5	7,718.74	12	1,102.49	7	2,743.46	6	299.09	3	219.27	7	195.67
Charlestown											1	9.62
Chelsea			2	896.82							1	9.77
Dighton			1	59.82								
Dorchester							1	37.85				
East Boston							1	248.19			1	103.48
Fall River			1	34.13			1	84.78	2	170.96	7	563.10
Gloucester			1	30.83	1	26.14	2	53.91			1	33.95
Haverhill			1	35.16							1	26.63
Ipswich			1	16.56								
Lynn											1	10.33
Nantucket											1	7.18
New Bedford											1	10.46
Newburyport			1	45.51	1	115.06			2	323.88		
North Weymouth											1	46.77
Salisbury			2	64.96							1	6.67
Sheldonville			1	20.54					1	9.70		
Springfield							1	27.28			1	15.26
Taunton											1	5.16
Westport			1	39.97								
MICHIGAN	1	387.92	49	18,421.53	4	636.13	90	6,278.59	73	38,140.16	50	959.89
Algonac			1	263.37			3	299.40	1	636.99		
Allegan			1	160.61					2	414.61		
Alpena											2	9.07
Bangor							3	111.08	2	2,296.08	1	8.80
Bay City							2	161.53			1	6.49
Berlin									1	78.82		
Cadillac											1	37.37
Cheboygan							2	59.54				
Crockery							2	28.40			1	9.54
Detroit			9	4,635.05	4	636.13	12	2,156.49	13	8,135.48	11	201.52
Eastmanville							1	335.30				
East Saginaw			2	299.73			12	408.64	3	1,342.49	1	29.72
Fair Haven									1	244.46		
Ferrysburg			1	42.91			4	137.23			1	23.30
Gibraltar									7	3,231.13		
Grand Haven			3	617.75			13	334.65			5	170.49

Steam vessels of the United States—Conitnued.

Where built.	Ocean passenger steamers.		Inland passenger steamers.		Ferry boats.		Towing boats.		Freight steamers.		Other steamers.	
	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.
MICHIGAN—Continued.												
Grand Rapids			2	257.36							1	26.66
Houghton											1	8.37
Ionia											2	50.36
Lake Harbor											2	6.00
Lincoln							1	34.16				
Ludington							1	49.24				
Manistee											1	11.73
Marine City			13	7,434.21			3	368.20	17	9,327.30		
Marquette											1	6.86
Marysville									1	391.49		
Menominee											1	7.28
Monroe											1	6.80
Mount Clemens			2	225.79					2	149.63	3	78.78
Muskegon			1	16.88			11	274.90	1	56.58	2	16.73
New Baltimore							1	51.02				
Newport							1	33.74			1	41.83
Port Huron							7	1,088.93	5	4,429.32		
Rockwood									1	36.22		
Saginaw			1	381.81			3	93.25	1	884.03	1	61.59
Saint Clair									4	2,733.53		
Saint Joseph			1	90.17			1	25.48			1	7.00
Saint Martin's island							1	20.61				
Salsburg									1	1,456.11		
Saugatuck			2	358.60			4	86.17	1	57.78	4	71.31
Sault Ste. Marie									1	72.96	1	17.94
Sebewaing			1	78.24								
Spring Lake											2	25.96
Sugar Island							1	75.63			1	18.39
Trenton			5	2,978.16					7	1,921.60		
Vicksburg									1	243.55		
Winona			3	268.89								
Wyandotte	1	387.92	1	312.00			1	45.00				
MINNESOTA			15	1,480.44	1	63.76	9	1,003.07			1	7.02
Arcola			3	303.52								
Brainard							1	19.09				
Breckenridge			1	117.75								
Carver							1	135.34				
McCauleyville			1	119.08								
Minneapolis							1	59.88				
Osceola							1	188.21				
Ottawa			1	78.88								
Reed's Landing			[illegible]	267.35			2	116.19				
Saint Anthony			1	60.42								
Saint Paul							1	131.90			1	7.02
Stillwater			3	434.44			1	133.60				
Wabasha			1	60.50								
Waconta							1	218.86				
Winona			1	38.50	1	63.76						
MISSISSIPPI			7	645.03			2	53.56	5	218.62	2	25.22
Aberdeen									1	64.00		
Bay Saint Louis							1	18.00				
Biloxi			1	76.39								
Columbus									1	22.29		
Gainesville			3	343.81					1	46.94		
Grand Gulf											1	4.97
Logtown			1	46.14								
Pearl River							1	35.56				
Rodney											1	20.25
Vicksburg			1	104.50					2	85.39		
Wolf River			1	74.19								
MISSOURI			10	9,903.44	13	1,500.59	8	557.20	8	459.25	2	354.65
Boonville									2	109.14		
Brunswick					1	72.18						

Steam vessels of the United States—Continued.

Where built.	Ocean passenger steamers.		Inland passenger steamers.		Ferry boats.		Towing boats.		Freight steamers.		Other steamers.	
	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage
MISSOURI—Continued.												
Carondelet					1	277.08						
Clarksville							1	51.48				
Forest City							1	54.80				
Gasconade River					1	33.60						
Glasgow					1	81.14						
Harlem							1	91.66				
Kansas City									1	47.72		
Lime Creek									1	76.52		
Missouri City					1	27.83						
Osage City			1	64.44								
Poplar Bluff									2	59.62		
Rocheport			1	240.72	1	63.66						
Saint Joseph					1	180.00						
Saint Louis			16	8,785.28	5	737.32	5	359.26	2	166.25	2	354.65
Washington			1	3.00								
Waverly					1	27.78						
NEW HAMPSHIRE			4	216.21							2	14.73
Dover			1	17.12								
Manchester											1	5.00
Portsmouth			3	199.09							1	9.73
NEW JERSEY	4	2,259.67	74	17,936.86	20	9,305.51	68	4,916.77	10	3,380.28	39	2,404.08
Alloway's Creek							1	17.90			3	255.84
Atlantic City							1	16.78				
Belleville			1	23.16			2	61.03	2	317.16		
Bordentown			4	126.03			8	113.83	2	346.13	6	186.56
Bull's Ferry			2	1,053.60					1	71.02		
Camden	2	1,492.31	18	1,932.68	5	2,488.04	20	1,794.36	1	84.54	14	1,114.32
Elizabethport							2	43.93				
Fort Lee			1	444.17								
Gloucester											2	253.08
Hoboken			2	290.40	7	4,945.25	5	1,116.03	2	2,362.64	1	317.67
Jersey City			14	4,734.04	1	300.05	2	47.34			1	33.11
Kaighn's Point	1	637.87	1	198.70			2	125.53				
Keyport			23	8,366.25	3	1,561.75	5	600.91	1	76.68	3	21.41
Millville			1	218.69								
Newark			1	5.57								
New Brunswick	1	129.49	5	349.75	1	10.42	14	831.96			1	163.42
North Belleville							2	34.53	1	122.11		
Passaic							1	30.14				
Perth Amboy											2	24.99
Petty's Island							2	78.00			2	18.66
Saltersville											1	15.02
Shadyside			1	193.82								
Washington							1	4.50				
NEW YORK	25	40,891.78	284	122,025.85	109	49,893.48	300	17,016.80	68	51,830.86	169	7,527.00
Albany			7	2,079.39	1	16.23	16	775.20	1	62.92	5	49.35
Alexandria Bay			1	82.54							2	35.00
Athens			7	3,213.85	7	1,498.11	5	129.94				
Black River											1	8.39
Brewerton											1	18.70
Brooklyn	8	11,266.04	62	27,362.93	46	29,750.21	23	1,627.29	11	7,219.20	35	2,590.94
Buffalo			56	13,039.74	12	749.29	164	5,381.14	30	30,890.75	39	1,501.63
Caldwell			2	97.95								
Cape Vincent			1	53.08								
Carthage			1	37.73								
Chaumont											1	9.47
City Island									1	80.97	1	11.36
Clayton			3	1,346.78			1	119.09	1	128.78	1	9.38
Depauville			1	31.60								
Dunkirk							1	15.13				
Eddyville							1	15.37	1	3.00	2	14.62
Ellenville							1	26.60				
Essex			1	125.18								

Steam vessels of the United States—Continued.

Where built.	Ocean passenger steamers.		Inland passenger steamers.		Ferry boats.		Towing boats.		Freight steamers.		Other steamers.	
	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.
NEW YORK—Continued.												
Fayettville			1	24.46								
Frankfort											2	239.10
Geneva			1	26.12							1	6.08
Glenwood			2	20.91					1	25.04		
Grand Island			1	16.23							1	15.61
Greenbush							2	78.83				
Green Point	5	8,838.53	16	10,739.67	6	3,298.09	1	111.71			3	214.42
Havana											5	633.24
Hunter's Point			1	186.69								
Ilion											1	119.90
Ithaca											2	254.27
Kingston							1	65.40	1	124.61		
Lansingburg					1	39.06	3	52.63			1	5.20
Lockport			2	574.58			2	16.68			1	128.40
Malden							3	77.62	1	880.63		
Massena			1	42.95								
New Baltimore			5	942.36	3	711.32	11	713.78	1	1,232.51	1	10.37
Newburgh			11	999.86	1	418.86	14	1,044.53			3	48.23
New York	12	20,787.21	65	54,835.93	25	12,616.10	21	5,292.49	11	10,149.70	12	132.80
Northport			3	256.38								
Nyack			1	37.76			2	307.76			1	15.35
Ogdensburg			8	2,419.34	1	181.24	1	35.16			9	411.20
Olean							1	27.70				
Oswego			1	207.42			1	32.93	1	465.00		
Peekskill							1	12.03			2	26.49
Pillar Point											1	19.46
Port Jervis			1	8.86								
Poughkeepsie			1	36.37							3	100.66
Pultneyville			1	56.09								
Randolph			1	15.44								
Red Hook					1	28.68						
Rhinebeck											1	11.00
Rochester			2	156.80			1	53.00			1	11.75
Rockaway									1	20.90		
Rome									1	85.10		
Roundout			1	71.06	2	479.99	10	447.35	1	49.99	6	481.37
Schenectady											1	23.81
Seneca Lake							1	17.00				
Shooter's Island			1	146.87								
Sodus											1	30.84
South Brooklyn			1	49.68			1	10.77				
Staten Island			4	287.34			1	74.41	2	150.10		
Stratsburg			1	268.12								
Syracuse									1	161.83	4	131.20
Ticonderoga			1	643.14								
Tonawanda			1	529.61	1	23.28					1	21.08
Tottenville							3	118.70	1	99.83	1	18.51
Troy and West Troy			2	143.75	1	18.54	5	70.10				
Wappinger's Falls											1	16.68
Waterford							1	30.21				
Watertown											5	31.43
Watkins			2	173.02								
Whitehall							1	236.25				
Williamsburg			3	635.27	1	64.48					1	119.71
NORTH CAROLINA			15	1,352.29			3	26.00	1	91.42		
Chowan			1	120.66								
Drummond's Point							2	16.71				
Elizabeth City									1	91.42		
Fayetteville			3	330.25								
Kinston			1	62.87								
Leachville			1	52.90								
New Berne			1	194.56								
Port Caswell			1	48.76								
Washington			3	197.24								
Wilmington			2	295.21								
Windsor			1	42.62								
Winton			1	7.22			1	9.29				

Steam vessels of the United States—Continued.

Where built.	Ocean passenger steamers.		Inland passenger steamers.		Ferry boats.		Towing boats.		Freight steamers.		Other steamers.	
	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.
OHIO			158	70,585.34	27	2,131.08	79	9,382.11	46	42,625.30	35	1,390.37
Aberdeen			1	26.22								
Akron							1	59.58				
Ashtabula							1	108.06			1	6.38
Beverly			1	61.23	1	22.27						
Black River			2	453.83					2	2,337.02	1	18.71
Buffalo											1	21.05
Chambersburg			2	186.35								
Chillicothe							2	99.37			1	106.23
Cincinnati			79	45,780.45	11	1,454.97	16	3,128.98	1	45.01	2	107.96
Cleveland			22	14,528.86			25	2,507.30	36	37,743.10	9	363.04
Conneaut			1	4.25			6	1,276.43				
Defiance											1	68.17
Fairport									1	37.88		
Gallipolis					1	30.36						
Hockingport			1	133.65								
Huron			1	1,101.81			1	87.37	1	1,272.34	2	38.31
Ironton			10	1,215.29			1	359.86				
Lorain											2	36.58
Madison Dock											1	4.24
Manchester			3	292.14								
Marietta					1	20.69	2	185.86				
Maumee											1	8.56
Matamoras			1	96.65								
Middleport			2	367.12	3	105.19	3	575.57				
Minersville			1	21.29								
New Jerusalem			3	675.18			1	76.49				
Peninsula			1	59.60			2	119.76				
Perrysburg							1	169.17				
Point Carmen			1	121.94								
Point Harmar			8	1,838.63								
Pomeroy			1	78.52								
Portage River							1	18.15			1	4.50
Portland					1	36.66						
Portsmouth			10	1,962.27	2	116.02	3	190.20			1	88.99
Port Union											1	134.63
Racine					2	59.44						
Rock River											1	14.52
Sandusky			5	1,034.12					3	210.96	6	293.08
South Point			1	43.64			1	80.60			3	75.42
Steubenville					2	103.23						
Toledo			1	502.30			10	199.33	1	926.54		
Vermillion							1	29.98				
Wellsville					3	182.25	1	110.05	1	52.45		
OREGON			63	20,824.64	7	1,499.26	5	182.25	4	297.94		
Astoria			3	54.68								
Cape Hancock			1	5.68								
Cascades			6	4,113.70					1	51.64		
Celilo					1	34.05			1	45.20		
Conemah			6	1,937.75								
Coos			1	22.58								
Coquille River			1	39.46								
Corvalis			1	143.36								
Dallas			3	2,179.12	1	97.94			1	178.44		
Empire City			3	163.39			1	40.93				
Gardiner			2	104.02								
Marshfield			2	104.87								
Myrtle Point			1	85.56								
Oregon City			2	1,109.14								
Pioneer City			1	95.33								
Portland			26	10,321.01	4	1,256.56	3	127.88				
Saint Helen's			1	75.23								
Salem			1	47.14								
Skipanon			1	18.31								
Westport			1	204.31	1	110.71	1	13.44	1	22.57		
Yaquina Bay												

Steam vessels of the United States—Continued.

Where built.	Ocean passenger steamers.		Inland passenger steamers.		Ferry boats.		Towing boats.		Freight steamers.		Other steamers.	
	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.
PENNSYLVANIA	47	85, 695. 49	182	38, 460. 76	22	5, 330. 41	353	43, 334. 23	39	24, 344. 91	84	5, 999. 81
Belle Vernon					1	172. 37						
Brownsville			10	2, 995. 57	2	245. 05	1	159. 06	1	263. 52		
California			2	291. 79			1	147. 89				
Chester	24	53, 399. 17	13	2, 509. 50	2	1, 806. 55	15	781. 93	11	6, 226. 02	8	518. 57
Erie			2	21. 59			3	82. 01	1	311. 23		
Espy											5	347. 34
Freedom			3	456. 51	1	312. 04						
Gray's Ferry			1	10. 45								
Hamburg									1	127. 70		
McKeesport			1	64. 60	2	152. 95	1	105. 72				
Marcus Hook											1	34. 02
Middletown											3	216. 20
Newton Hamilton											1	49. 32
Philadelphia	23	32, 296. 32	88	8, 098. 72	9	2, 055. 98	181	9, 583. 03	17	13, 618. 19	63	4, 342. 06
Pittsburgh			60	22, 901. 61	5	585. 47	148	32, 446. 05	9	3, 704. 15	2	482. 30
Pittston			1	5. 37								
Reading							2	17. 75	1	94. 10	1	10. 00
Shorestown			1	1, 105. 05								
Titusville							1	10. 79				
RHODE ISLAND			4	143. 59			1	8. 39			12	292. 18
Apponaug			1	23. 64							1	38. 24
Bristol							1	8. 39			11	253. 94
East Providence			2	35. 48								
Westerly			1	84. 47								
SOUTH CAROLINA			6	1, 251. 65			3	44. 47			1	13. 19
Charleston			4	926. 84			3	44. 47			1	13. 19
Georgetown			2	324. 81								
TENNESSEE			19	2, 003. 81	1	314. 84	4	47. 71	2	72. 37		
Calhoun			1	55. 45								
Chattanooga									1	48. 18		
Clarksville			1	55. 75								
Dandridge			1	49. 40								
Dyersburg			2	201. 11								
Henry's Mill			1	162. 17								
Kingston			4	772. 96								
London			1	146. 16								
Memphis			3	174. 29	1	314. 84	4	47. 71				
Nashville			5	386. 52					1	24. 19		
TEXAS			1	185. 95			5	157. 93	1	65. 83		
Galveston			1	185. 95								
Houston							1	35. 65				
Lynchburg							4	122. 28				
Orange									1	65. 83		
VERMONT			2	1, 399. 06								
Burlington			1	274. 53								
Shelburne			1	1, 124. 53								
VIRGINIA	1	1, 437. 96	25	3, 492. 99	3	445. 94	17	379. 32	8	527. 37	2	17. 70
Accotink			1	297. 70					1	51. 14		
Alexandria			2	89. 91	1	49. 94	4	77. 94			1	9. 10
Atlantic City			1	938. 65								
Berkeley			2	63. 58			3	56. 95				
City Point							1	30. 40				
Cole's Ferry			1	40. 00								
Cottsville									1	42. 47		
Gilmington Locks			1	116. 62								
Neabsco									1	60. 77		
Norfolk			12	1, 522. 86	1	116. 06	4	104. 26	2	138. 33	1	8. 60
Occoquan			1	51. 33								

Steam vessels of the United States—Continued.

Where built.	Ocean passenger steamers.		Inland passenger steamers.		Ferry boats.		Towing boats.		Freight steamers.		Other steamers.	
	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.
VIRGINIA—Continued.												
Portsmouth			1	37.35	1	279.94						
Port Walthall							1	15.95				
Richmond	1	1,437.96					4	93.82	2	70.87		
Smithfield									1	163.79		
Washington Point			3	334.99								
WASHINGTON TERRITORY	1	732.36	31	3,279.88	1	181.81	1	110.59	3	63.01		
Bell Town			1	96.10								
Columbus			1	356.18								
Knappton			1	7.34			1	110.59				
Olympia			2	133.33					1	24.23		
Point Blakeley			1	176.01								
Point Discovery			1	194.35								
Port Gamble			1	173.54								
Port Madison	1	732.36	2	103.25								
Point Orchard			1	39.18								
South Bend			1	76.09								
Seattle			10	1,014.89					2	38.78		
Seabeck			1	83.31	1	181.81						
Snohomish City			1	37.62								
Turnwater			1	96.72								
Utsalady			4	540.17								
Vancouver			1	130.05								
Waterford			1	21.75								
WEST VIRGINIA			27	4,683.80	10	532.19	14	2,010.21	2	78.49	1	3.00
Burning Springs			1	83.32								
Charleston			4	196.67								
Guyandotte			1	55.71								
Hinton			1	146.96								
Leon			1	60.95								
Mason City			1	50.50	1	48.08						
Murraysville			4	820.49	1	49.05	1	52.19				
New Cumberland					1	25.00						
Parkersburg			5	554.90			1	8.60				
Peyton							1	23.91				
Point Pleasant			1	59.57	1	55.91						
Ravenswood									1	18.76		
West Columbia					1	30.31						
Wheeling			8	2,654.73	5	323.84	11	1,925.51	1	59.73	1	3.00
WISCONSIN			59	12,746.39	5	148.76	61	2,649.75	18	2,332.22	15	297.95
Ahnapee							2	42.20				
Baytown					1	33.04						
Berlin							2	146.44				
Chippewa Falls							1	37.59				
De Pere							1	13.55	1	90.08		
De Soto			1	51.64								
Eureka							1	20.00				
Fort Howard			5	144.15			4	70.80				
Green Bay			4	759.65			2	123.81	1	75.25	3	52.23
Hudson			1	61.73	1	26.98						
La Crosse			10	2,802.45			7	639.71				
Little Sturgeon							1	50.00				
Little Wolf									1	80.00		
Maiden Rock			1	98.78								
Manitowoc			9	5,654.15			2	29.24	1	68.68	1	10.65
Manistee									1	365.38		
Menasha									1	70.00		
Menominee			2	170.66								
Milwaukee			4	898.03	1	25.00	13	564.30	4	313.86	5	106.82
Montella			1	30.00								
Oconta			1	28.49								
Oshkosh			6	606.89			11	371.97	4	674.08		
Packwaukee									1	90.00		
Pensaukee							1	34.06	1	118.95		
Prescott			1	236.86			1	111.52				

Steam-vessels of the United States—Continued.

Where built.	Ocean passenger steamers.		Inland passenger steamers.		Ferry boats.		Towing boats.		Freight steamers.		Other steamers.	
	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.	No.	Tonnage.
Port Washington			1	66.51								
Pepin			2	162.83	1	24.74						
Peshtigo							1	50.00				
Prairie du Chien			1	242.14			1	21.03				
Racine											1	8.00
Red River							1	22.58				
Shawano			1	69.37								
Sheboygan			1	433.05			2	46.65	1	285.94	3	99.80
Sturgeon Bay							1	75.25				
Superior City											1	5.24
Two Rivers							1	18.49			1	15.21
Wabasha					1	39.00						
Winneconne			4	226.00			5	157.56	1	100.00		

STEAM VESSELS OF THE ATLANTIC AND GULF DISTRICTS.

Geographical distribution.—In order to furnish a comprehensive view of the disposition and service of the steam tonnage, the steamers have been classified according to their usual routes and service in the following summary. Such route or service is sometimes indeterminate or a matter of question, but by the aid of occasional explanations and qualifying remarks the whole subject is believed to be fairly outlined.

Foreign trade.—There are few steamers plying to foreign ports. From Philadelphia to Liverpool, England, the American line has four steamers running, which are inspected in this country. They aggregate 12,408.12 tons, and have four engines, cylinder capacity, 1,010.44 cubic feet. The following steamers may be specified as plying to South American ports, the West Indies, Panama, Honduras, Mexico, and Central America:

[These are aggregate figures. The number of cubic feet will be understood as the aggregate cylinder capacity.]

Where from.	Steamers.	Tons.	Engines.	Cubic feet.
New England	4	4,625.10	8	274.25
New York	20	46,939.32	22	3,170.55
Philadelphia and ports southward on the Atlantic coast	3	979.70	4	25.51
New Orleans and Gulf ports	1	508,05	1	14.68
	2	706.86	3	30.85

A number of other large steamers in the coasting trade, routes unspecified, run to the West Indies. (See coasting from New York and Philadelphia, unspecified, and coasting between Gulf and Atlantic ports.)

A few steamers are specified as running to Canadian ports on the Atlantic seaboard:

Where plying.	Steamers.	Tons.	Engines.	Cubic feet.
Running to Canadian ports on the Atlantic seaboard	4	4,538.66	4	627.45
	1	935.28	1	138.23
	1	282.68	1	25.64
	3	115.13	3	8.15
	3	37.51	3	14.68

Nearly all of these, and all of the small ones run from New England ports. The steamers are grouped by sizes according to the system of classification which has been previously explained. Some run both to the West Indies and to Halifax.

COASTING TRADE.—Under this head are grouped the principal elements of the coasting trade by steam vessels. This is more or less merged with sound, bay, and river service, which are separately considered, and the many large steamers plying through Long Island sound do not appear under this head.

Where plying.	Steamers.	Tons.	Engines.	Cubic feet.
Coasting from New York, not otherwise specified	6	9,158.56	9	539.50
	4	2,927.73	4	331.01
	6	1,198.74	7	108.29
	15	1,103.19	15	69.84
	1	49.86	1	1.43
	1	4.00	1	0.23
Coasting from Philadelphia, not otherwise specified	12	16,089.16	13	454.39
	14	10,236.66	14	328.31
	11	3,526.12	11	179.04
Coasting from Boston and other New England ports to specified points south of New York	9	13,061.64	11	700.19
	5	4,062.70	6	181.91
	1	188.46	1	8.62
	16	1,284.24	16	44.21
Specified as coasting from New York to Baltimore, Charleston, Savannah, and other Atlantic ports of the southern states.	14	26,076.82	15	2,476.94
	6	5,410.20	6	769.30
	11	4,174.22	11	186.58
Specified as coasting from Philadelphia and Baltimore to Atlantic ports of the southern states (see also Baltimore to Norfolk and coasting from Philadelphia, unspecified).	3	1,825.47	5	102.59
	1	432.43	1	9.97
	1	65.86	1	3.99
Between Charleston, Wilmington, and Savannah, specified. (See also the following)	6	1,216.82	7	135.86
	1	52.61	1	3.63
	2	74.32	2	3.76
	1	7.74	1	0.36
Coasting between Atlantic ports of the southern states, not otherwise specified	3	3,424.03	3	532.83
	1	678.06	1	121.50
	4	548.72	4	49.14
	4	270.54	4	16.48
	4	155.85	4	7.17
	1	21.00	2	0.53
Running from Gulf and Atlantic ports to Key West. Most of these are from Gulf ports	6	1,419.66	8	57.93
	1	36.84	1	3.63
Plying between Gulf and Atlantic ports, mainly between New York and New Orleans	13	24,991.63	15	1,072.02
	1	508.68	1	113.09
	1	105.01	2	11.98
	1	85.50	1	11.34
Coasting upon the Gulf of Mexico, not otherwise specified. (See also bays, rivers, and coasting)	11	14,166.98	12	1,318.09
	6	4,627.96	6	452.71
	1	70.69	2	2.48
Coasting from Boston to points northward in New England	5	6,131.45	[illegible]	947.71
	1	86.84	1	2.46
	2	75.86	2	3.57

PRINCIPAL SOUND AND COASTING SERVICE.

Where plying.	Steamers.	Tons.	Engines.	Cubic feet.
New York to ports on Long Island sound and tributaries	15	20,549.84	16	3,986.51
	4	3,124.41	4	567.50
	13	3,525.41	13	332.72
	9	645.00	10	48.97
	2	79.79	2	4.63
	4	32.83	4	0.41
New York to ports in New England beyond Long Island sound	9	19,669.91	10	3,928.77
	5	3,964.04	9	189.40
	4	1,371.97	5	98.29
	1	92.17	1	12.28
Long Island sound, and coasting, not otherwise specified	1	1,420.52	1	138.23
	2	1,391.39	2	106.70
	13	2,611.05	15	243.04
	27	2,009.75	29	82.91
	18	672.44	19	27.41
	30	393.19	33	14.51
Plying upon Albemarle and Pamlico sounds, and from Chesapeake bay to the sounds of North Carolina.	18	3,896.23	21	165.22
	16	1,194.33	22	30.71
	11	353.75	11	11.91
	23	285.45	24	9.21
Sounds and inlets of Florida and Georgia, and upon Saint John's river	13	3,144.59	19	347.45
	13	896.77	20	66.65
	6	216.51	9	20.96
	18	142.94	21	4.46

The sounds to which reference is made have, as will be seen, a considerable and a characteristic body of steam shipping. The steamers of other sounds, inlets, and bays will be found classified under other heads.

PRINCIPAL BAY SERVICE.

Where plying.	Steamers.	Tons.	Engines.	Cubic feet.
Narragansett and Buzzard bays, rivers, and coasting	1	1,691.53	1	377.60
	8	5,120.46	8	918.81
	13	3,315.83	13	415.23
	20	1,377.39	22	61.71
	10	396.14	10	18.90
	26	269.30	30	10.83
Massachusetts bay, local and coasting	1	1,372.29	2	63.34
	7	3,643.73	7	547.44
	23	7,290.33	27	935.14
	7	489.17	8	22.44
	32	1,164.10	34	56.55
	26	312.74	28	14.95
New York bay, and bays and inlets of the New Jersey coast. This is exclusive of the regular ferry boats (see also New York and inland).	9	13,851.31	12	1,854.53
	7	4,366.44	7	663.25
	59	12,091.32	81	1,242.93
	88	5,883.49	89	478.43
	119	4,388.21	121	277.57
	76	1,089.50	81	67.52
Chesapeake bay and tributaries, not otherwise specified (see also Potomac river, Patapsco river, Baltimore and inland; and Chesapeake bay to North Carolina sounds).	13	8,359.50	15	1,262.23
	19	5,969.45	20	734.45
	9	629.53	9	59.87
	27	1,019.36	28	70.84
	11	159.20	11	8.57

PRINCIPAL GROUPS OF FERRY BOATS AND STEAMERS ON SHORT RIVER ROUTES.

Where plying.	Steamers.	Tons.	Engines.	Cubic feet.
New York bay ferries	7	7,341.04	7	1,123.18
	56	38,426.82	56	5,431.42
	21	7,683.36	21	1,088.95
Hudson river ferries	12	2,971.14	12	472.91
	4	295.33	5	19.85
	1	39.06	2	1.08
	5	70.40	7	2.06
Delaware river ferries and short routes (see also Philadelphia to Delaware bay and river)	1	536.51	1	70.69
	13	4,719.43	13	815.27
	1	97.25	1	7.98

PRINCIPAL RIVER AND CANAL SERVICE.

Where plying.	Steamers.	Tons.	Engines.	Cubic feet.
Rivers and coasting north of Massachusetts bay	1	1,127.52	1	162.14
	1	874.98	1	138.30
	14	2,851.01	19	244.99
	13	957.15	14	76.46
	28	1,069.23	34	54.36
	34	398.11	38	14.68
New York to Hudson river points specified. (See also New York to Troy and Albany)	5	8,784.39	5	1,888.07
	11	7,624.98	11	1,676.75
	19	5,235.87	20	1,059.62
	3	251.00	3	30.08
	1	29.57	1	1.01
	7	51.98	8	2.68
Specified as plying between New York and Troy and Albany	4	5,380.09	4	1,047.24
	5	3,306.16	5	1,336.99
	6	1,942.12	6	1,026.18
	1	57.12	1	12.58
	1	40.17	1	2.62
Plying between specified Hudson river ports. (See also Hudson river ferries)	2	1,204.71	2	200.57
	6	1,896.94	6	421.16
	2	157.32	3	8.71
	1	4.00	1	0.04
Running from New York inland by sound, river, and canal routes unspecified. (See also Buffalo and New York).	15	10,149.50	15	1,715.47
	39	8,811.70	41	1,300.98
	37	2,642.03	38	325.94
	23	867.44	25	50.98
	22	297.77	26	13.52

PRINCIPAL RIVER AND CANAL SERVICE—Continued.

Where plying.	Steamers.	Tons.	Engines.	Cubic feet.
Running from Hudson river points inland by river and canal routes unspecified	8	1, 653. 29	5	472. 58
	13	919. 57	13	147. 85
	23	792. 73	24	72. 55
	61	795. 38	61	50. 07
Philadelphia to Delaware bay and specified points on Delaware river. (See also Delaware river ferries.	1	637. 20	2	245. 98
	12	2, 723. 01	16	790. 28
	5	349. 72	6	41. 13
	3	89. 85	3	3. 93
	46	413. 03	47	25. 10
Philadelphia, Camden, Wilmington, ana Trenton inland by routes unspecified	3	3, 464. 84	4	603. 23
	8	5, 051. 35	9	1, 066. 84
	47	11, 317. 17	47	767. 10
	26	1, 935. 79	26	126. 22
	52	1, 983. 13	52	123. 79
	31	569. 38	32	30. 11
Plying upon the James river, and between Norfolk and Richmond and Baltimore	7	5, 094. 03	7	657. 76
	7	2, 559. 41	7	241. 89
	6	387. 90	6	15. 82
	14	497. 44	15	26. 56
	11	159. 28	11	7. 11
Patapsco river, Baltimore harbor, and to points inland	6	4, 163. 36	7	701. 62
	12	3, 864. 50	13	311. 07
	6	424. 62	6	17. 45
	6	221. 73	6	13. 57
	30	428. 81	31	26. 65

A number of the larger steamers ply from Baltimore to Fredericksburg, on the Rappahannock river. See also Norfolk and Richmond to Baltimore and Chesapeake bay and tributaries. Under this last head are a number of steamers specified as plying from points on the Choptank, Nanticoke, York, and Patuxent rivers.

Where plying.	Steamers.	Tons.	Engines.	Cubic feet.
Upon the Potomac river and from Washington and Georgetown, District of Columbia, to points inland. (Not comprised under any previous head and not duplicated in the classification.)	8	2, 253. 74	9	286. 17
	5	296. 47	6	9. 59
	11	468. 54	12	20. 58
	9	131. 50	[illegible]	8. 58
Winyah bay, Santee, Pedee, and Cape Fear rivers, and South Carolina harbors	13	3, 117. 45	22	209. 02
	8	630. 16	10	49. 87
	11	425. 19	13	23. 64
	13	174. 98	14	5. 83
Altamaha and Savannah rivers	5	886. 57	10	71. 84
	8	664. 61	10	49. 61
	7	272. 17	7	24. 02
	7	53. 79	9	1. 36
Rivers and bays of the Gulf of Mexico west of the Mississippi	1	892. 51	1	150. 33
	15	3, 498. 38	27	126. 64
	7	475. 98	10	17. 62
	10	366. 64	12	18. 29
	10	125. 67	10	4. 34
Rivers and bays of the Gulf of Mexico east of the Mississippi	1	592. 20	2	5. 12
	33	8, 022. 05	55	552. 06
	24	1, 746. 07	34	129. 00
	15	573. 08	20	30. 01
	24	311. 94	29	17. 08

This last group is comprised mainly in the steamers plying on Mobile bay and the Alabama and Tombigbee rivers, the Apalachicola and Chattahoochee rivers to Columbus, Georgia, and a smaller number plying on Pensacola bay, Escambia river, Choctawhatchie bay, and from Cedar Keys to points on the Suwanee river. West of the Mississippi the steamers above specified ply mainly on Galveston bay, but some upon the Sabine and Calcasieu lakes and rivers.

The following table exhibits the distribution of steamers inspected at New England ports. It is covered by the foregoing classification. It is believed that a better general idea of the distribution and service of the steam tonnage of the United States can be obtained by thus grouping the steamers than in any other manner.

	STEAMERS OF 1,000 TONS AND OVER.				STEAMERS OF 500 TO 1,000 TONS.				STEAMERS OF 100 TO 500 TONS.			
	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.
Long Island sound, rivers and coasting	1	1, 420. 52	1	138. 23	2	1, 391. 39	2	106. 70	13	2, 611. 05	15	243. 04
Specified as running from points in Connecticut to New York	14	18, 939. 89	14	3, 919. 65	2	1, 985. 25	2	325. 28	3	1, 312. 05	3	41. 43
Narragansett and Buzzard bays, rivers and coasting	1	1, 691. 53	1	377. 66	8	5, 120. 46	8	918. 81	13	3, 315. 83	13	415. 23
Specified as running to New York from New England ports beyond Long Island sound	9	19, 669. 91	10	3, 928. 77	5	3, 964. 04	9	189. 40	4	1, 371. 97	5	98. 29
Massachusetts bay, local and coasting	1	1, 372. 29	2	63. 34	7	3, 643. 73	7	547. 44	23	7, 299. 33	27	935. 14
Specified as plying between Boston and points northward in New England	5	6, 131. 45	5	947. 71								
Specified as running to the West Indies from New England ports	4	4, 625. 10	6	274. 25								
Specified as running to Canada from New England ports	3	3, 292. 48	3	575. 86	1	935. 28	1	138. 23	1	282. 68	1	25. 64
Rivers and coasting north of Massachusetts bay	1	1, 127. 52	1	162. 14	1	874. 98	1	138. 39	14	2, 851. 01	19	244. 99
Specified as coasting to southward of New York from New England ports	4	6, 734. 69	6	403. 75					1	188. 46	1	8. 62

	STEAMERS OF 50 TO 100 TONS.				STEAMERS OF 25 TO 50 TONS.				STEAMERS OF LESS THAN 25 TONS.			
	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.
Long Island sound, rivers and coasting	27	2, 009. 75	29	82. 91	18	672. 44	19	27. 41	30	393. 19	33	14. 51
Specified as running from points in Connecticut to New York	4	294. 46	5	16. 25	1	40. 39	1	3. 63	3	13. 32	3	0. 38
Narragansett and Buzzard bays, rivers and coasting	20	1, 377. 39	22	61. 71	10	396. 14	10	18. 90	26	269. 30	30	10. 83
Specified as running to New York from New England ports beyond Long Island sound	1	91. 27	1	12. 28								
Massachusetts bay, local and coasting	7	489. 17	8	22. 44	32	1, 164. 10	34	56. 55	26	312. 74	28	14. 95
Specified as plying between Boston and points northward in New England	1	86. 84	1	2. 46	2	75. 86	2	3. 57				
Specified as running to the West Indies from New England ports												
Specified as running to Canada from New England ports					3	115. 13	3	8. 15	3	37. 51	3	1. 25
Rivers and coasting north of Massachusetts bay	13	957. 15	14	76. 46	29	1, 114. 30	35	55. 59	34	398. 11	38	14. 68
Specified as coasting to southward of New York from New England ports	16	1, 284. 24	16	44. 21								

STEAMERS IN FOREIGN TRADE.

The engines of the steamers of the American Steamship company (plying between Philadelphia and Liverpool) are of the most usual compound type, and will hereafter be more fully described. The cylinders are 57 and 90 inches in diameter with 4 feet stroke of piston.

Of steamers running to Panama, West Indies, Mexico, and South America the following examples of engines may be cited:

The "United States", 1,180.10 tons, plying from Boston, has two simple engines, vertical, surface-condensing, 40 inches diameter of cylinder, 40 inches length of stroke. The "City of Vera Cruz", 1,874.36 tons, of the New York and Havana Mail Steamship company's line, has one simple surface-condensing engine, 4 feet diameter of cylinder, 6 feet length of stroke. This engine has some peculiar features. The valve-gear is of the Corliss type, and was designed by George Reynolds, of New York. The pumps are operated by an auxiliary engine, which is bolted upon the starboard (right hand looking forward) side of the frame. This auxiliary engine is a beam-engine, the beam extending across the top of the condenser and driving the pumps, which are all located upon the port side, an arrangement somewhat different from that of the Pacific Mail steamships, in which the auxiliary engines and the pumps are both located upon the starboard side below the main engine-cylinders. The feed from the hot-well passes through a filter 10 feet long by 6 feet wide by 3½ feet deep. This filter contains 5 wooden frames, covered with heavy wool blankets and wire netting, between which is a filling of coke. The feed has a temperature of 120°. The "City of Merida", 1,492.45 tons, running between New York and Vera Cruz, has one vertical condensing-engine, cylinder 56 inches by 4½ feet.

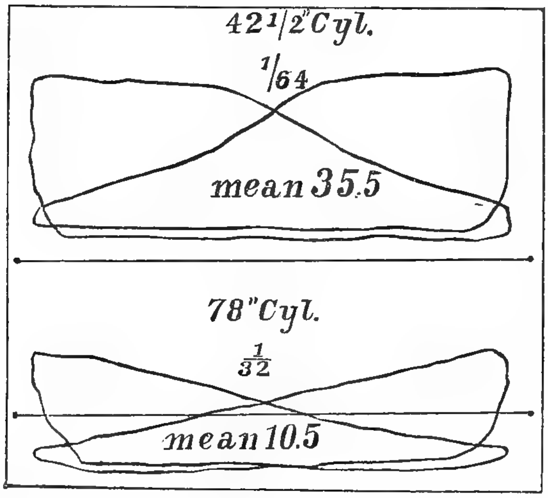


FIG. 2.

The "City of Para", of the Brazilian line (tonnage of steamer 3,532.25), has one compound engine, 42½- and 74-inch cylinders by 5-foot stroke, built by Messrs. John Roach & Son. The "Newport", 2,735.29 tons, running between New York and Cuba, has one compound engine, 48- and 90-inch cylinders by 4½ foot stroke. The "City of Alexandria", 2,480.32 tons, of F. Alexandre Sons, Havana and Mexican Mail line, has one compound engine, 42½- and 78-inch cylinder diameters by 54-inch stroke. Cards of the engine are shown in Fig. 2, and the data of performance are as follows:

Area, high-pressure cylinder .... square inch..	1,418.63
Area, low-pressure cylinder .... do......	4,778.37
Ratio of cylinders	3.3683
Stroke .... feet..	4½
Boiler pressure per square inch .... pounds..	70
Receiver pressure per square inch .... do....	10
Vacuum .... inches..	26
Revolutions per minute	60
Mean pressure, high-pressure cylinder .... pounds..	35.5
Mean pressure, low-pressure cylinder .... do....	10.5
Indicated horse-power, high-pressure cylinder	824
Indicated horse-power, low-pressure cylinder	821
Total	1,645

The absolute terminal pressure is stated at 9.56 pounds.

The "Tropic", 379.77 tons, plying between Philadelphia and the West Indies, has two 24- by 24-inch engines, simple condensing. The "Acadia", 387.26 tons, has one 32- by 30-inch simple condensing-engine.

The "Margaret", 508.05 tons, plying between New Orleans and Havana, has one simple condensing-engine, 32-inch cylinder by 32-inch stroke, and the "E. B. Ward, jr.", 387.92 tons, running to Honduras, has two 30- by 30-inch simple condensing-engines.

SMALL NUMBER OF COMPOUND ENGINES IN THE ATLANTIC AND GULF SERVICE.

Upon the large steamers of New England there may be said to be scarcely any compound engines, the only considerable proportion of them being in the small steam yachts. The practice is so diametrically opposed to that of the Pacific district, that it is emphasized by the following table of the percentages of compound to total number of engines in the two districts:

Tonnage of steamers.	New England.	Pacific.
	Per cent.	*Per cent.*
Over 1,000 tons	4	45
500 to 1,000 tons	0	11
100 to 500 tons	$1\frac{1}{8}$	10
50 to 100 tons	2	2
25 to 50 tons	2	5
Under 25 tons	0	0

In the Pacific district 45 compound engines propel 40,075.10 tons of shipping, the engines having an aggregate cylinder capacity of 2,914.24 cubic feet, and employing a boiler volume of 95,225.15 cubic feet; while 256 simple engines propel 70,496.21 tons of shipping, the engines having an aggregate cylinder capacity of 5,773.86 cubic feet, and employing a boiler volume of 150,475.04 cubic feet. In the New England district, comprising steamers inspected at the ports of Portland, Maine; Boston, Massachusetts; and New London, Connecticut, 17 compound engines propel 2,719.99 tons of shipping, the engines having an aggregate cylinder capacity of 111.71 cubic feet, and 10 of these have small coil boilers. The remaining 7 propel 2,565.21 tons of shipping, and employ a boiler-volume of 6,010.11 cubic feet, while 471 simple engines propel 110,999.09 tons of shipping, the engines having a cylinder capacity of 15,605.08 cubic feet, and employing a boiler volume of 398,389.81 cubic feet.

The percentage of tonnage of steam shipping propelled by compound engines is, for the Pacific district .3624, and for New England, .0024, river service included.

The cylinder capacity per 100 tons shipping is:

	Cubic feet.
For the compound engines:	
Pacific district	7.27
New England district	4.10
For the simple engines:	
Pacific district	8.19
New England district	14.05

The boiler volume per 100 tons is:

For steamers with compound engines (exclusive of steamers with coil boilers):	
Pacific district	237.59
New England district	234.29
For the steamers with simple engines:	
Pacific district	213.45
New England district	358.91

Designating as classes I, II, III, IV, V, and VI the groups of steamers of over 1,000, 500 to 1,000, 100 to 500, 50 to 100, 25 to 50, and under 25 tons respectively, we find among steamers inspected at Albany that none have compound engines in Class I, none in Class II, none in Class III, 3 out of 19 in Class IV, 1 out of 25 in Class V, and 1 out of 67 in Class VI.

Among steamers inspected at New York we find compound engines in only 19 out of 65 steamers of Class I, although this class includes many of the largest coasters. It may be remarked that of the remaining 46 steamers, 20 have beam-engines condensing and 26 simple-condensing direct-acting engines. From this it will be seen that there are 45 propellers to 20 side-wheel boats.

On steamers in Class II (500 to 1,000 tons) inspected at New York there is not, strange as it may appear, a single compound engine; but in Class III we find 12 steamers out of 162 with such engines, several being of the three-cylinder type. In Class IV, we find 4 out of 149 steamers with compound engines; in Class V, 6 out of 145; in Class VI, 6 out of 115.

Steamers inspected at Philadelphia having compound engines: Class I, 5* out of 21; Class II, 1 out of 30; Class III, 9 out of 88; Class IV, 6 out of 34; Class V, none; Class VI, none.

The remaining steamers in the Atlantic and Gulf service having compound engines may be very briefly enumerated: 4 or 5 inspected at Baltimore (small vessels), 1 inspected at Charleston, the 4 large steamers of the (Savannah) Ocean Steamship company,† the "Chalmette", of New Orleans, and a few small steamers upon the Gulf.

* Four steamships of the American line and the collier Perkiomen. † Not including the City of Augusta, which was inspected at New York.

COMPOUND ENGINES OF AN OCEAN STEAMER AS BUILT BY MESSRS. NEAFIE & LEVY, PHILADELPHIA.

The dimensions of machinery of a compound engine of American build are very fully given in the following figures:

Main steam-cylinders: Diameters, 30″ and 50″; stroke, 3 feet; stuffing-box, 10½″ diameter.

Ports and valves: 3″ by 20″ high-pressure steam-port, 3″ by 36″ low-pressure steam-port, 4½″ by 20″ high-pressure exhaust-port, 4½″ by 36″ low-pressure exhaust-port.

Relative area of ports: High-pressure steam, 60 square inches, as 1; low-pressure steam, 108 square inches, as 1.8; high-pressure exhaust, 90 square inches, as 1.5; low-pressure exhaust, 162 square inches, as 2.7; 2″ slide-valve lap, 5½″ depth of slide-valve, 5½″ upper width cut-off valve, 5″ lower width cut-off valve.

Valve-gear measurements: 9″ center to center front links; journals 2¼″ diameter, 2¼″ long; 6¼″ steam-valve motion; 2¼″ diameter of valve-stem; journals 2¼″ diameter, 3″ long; 1⅞″ diameter of cut-off valve-stem, journals 1½″ diameter, 2″ long; 8′ 1½″ radius of slotted link; dimensions of slotted link, 16½″ cross motion, 3″ width, 1½″ thickness, 2¼″ and 3″ diameters of eyes; reversing-shaft, 3¾″ diameter.

Valve-chests: 2′ 6″ center cylinder to valve-face (high pressure); 2′ 10″ center cylinder to valve-face (low pressure); 3′ 6″ center cylinder to chest-face (high pressure); 3′ 8″ center cylinder to chest-face (low pressure); depth of chests, 12¾″ and 10¾″; centers of cylinders to centers of valve-stems, 32½″ and 36″; 3′ 4″ center cylinder to cut-off stem.

Piston: 8″ depth of piston at center, 7″ depth of piston at edge, ¾″ thickness of rings, 4½″ diameter of piston-rod.

Cross-head: 11″ main diameter, 9″ long; journal 5″ diameter, 5½″ long.

Connecting-rod: 7′ 6″ long, center to center of journals, neck diameters 4″ and 5″.

Crank and shaft: Crank-pin 8½″ diameter, 11½″ long; main-shaft journals 9½″ in diameter, length 15½″ forward, 15″ aft; 17″ diameter of upper end of crank, 18″ diameter of lower end of crank; 8″ thickness of crank.

Pinch-wheel: 4 feet diameter, 5″ face; shaft-couplings 16½″ diameter, 10″ depth, 24½″ diameter of flange.

Eccentrics: 9½″ diameter of eccentric eye, 3½″ eccentric face, 6½″ eccentric throw, 19½″ eccentric diameter.

Bed-plate and housings: Bed-plate 9′ 8″ long, 6′ 9″ broad, 6½″ center of shaft to top of bed-plate; housings 9′ 9″ high, 23½″ by 32″ at base, 20″ by 24″ at top.

Stern-bearing: 10½″ diameter, 48″ long.

Main guides: 9″ face, 1″ side depth.

Gibs: 18″ long, 1½″ thick.

Air-pump: 17″ diameter of cylinder, 15″ stroke, 4½″ depth of piston at center, 3⅞″ depth of piston at edge, 2″ diameter of pump-rod, 8″ diameter injection-side; air-pump cross-head 5½″ diameter, journals 3″ diameter, 3″ long; air-pump links 3′ 9″ center to center; air-pump levers 1½″ thick, journal cylinder end 2¼″ diameter, 2¼″ long; air-pump end 3″ diameter, 3″ long, center diameter 4″ by 15″ length.

Other pumps: Centrifugal circulating-pump 120″ diameter, with 5½″ by 6″ steam-cylinder, 8″ discharge- and 10″ receiving-pipe. A feed- and a bilge-pump each 3½″ diameter by 15″ stroke.

Propeller: 10′ 9″ diameter, 4′ 8″ length of blade, 15′ 9″ pitch.

The cylinder volume swept by pistons per revolution is 111.45 cubic feet, 26.43 per cent. in the high-, 73.57 per cent. in the low-pressure cylinders. The air-pump passes 1.97 cubic feet, the feed- and bilge-pumps each nearly 0.075 cubic feet per stroke.

COMPOUND ENGINES OF THE AMERICAN STEAMSHIP COMPANY'S VESSELS.

These engines, built by W. Cramp & Sons, Philadelphia, have been frequently described, and were illustrated in the London journal *Engineering*, in 1876. The following description of the machinery and its performance may be cited:

The engines are independent, compound, and surface-condensing, with the cranks set at right angles. The cylinders are 57¼″ and 90⅛″ in diameter respectively, and the stroke of pistons is 4 feet. The main slide-valves are on the outside of the high- and low-pressure cylinders, which are both inclosed in a jacket connecting them together and forming a receiver. The high-pressure cylinder is also steam-jacketed, but the low-pressure cylinder is not. The pistons are 16¾″ deep; the rod for the high-pressure cylinder is 8″, and that of the low-pressure 8½″ in diameter, and both are carried upwards through the cylinder-heads. The cross-heads are of wrought iron, with cast-iron slides bolted to their ends. The main slide-valves have double ports; each is fitted with an independent cut-off valve on the back, no provision being made for counterbalancing the pressure on the valve-faces. The weight of the main valves is counterbalanced by the steam-pressure in a cylinder on the top of the steam-chest. Both main valves are driven by motion of the double-bar-link type.

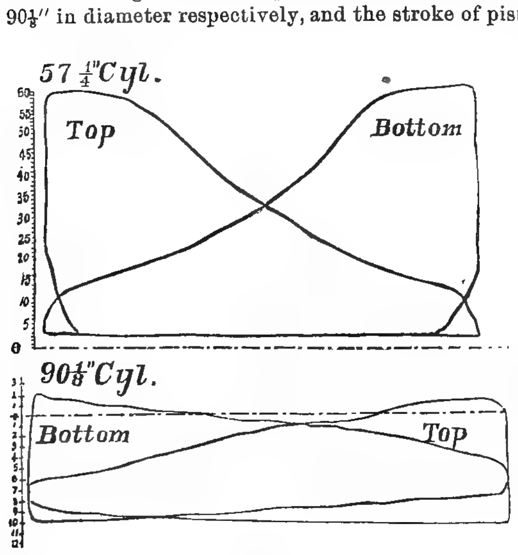


FIG. 3.

The engines are reversed by direct-acting steam-gear, the reversing-cylinder being 20″ in diameter, with a slide-valve on top, whichis thrown open by hand and closed by the motion of the piston-rod in any position. A screw is also provided, which can be clamped to the piston-rod of the cylinder so as to move the links by hand if there is a want of steam.

Relief-valves are fitted at the end of each cylinder with gear to use them as starting-valves. The connecting-rods are forked at the cross-heads and are fitted with strap ends. The cross-head journals are 10½″ in diameter and 10½″ long, and the crank-pins are of steel, 15¼″ in diameter and 20″ length of journals. The crank-shafts are built up in two lengths and are made interchangeable; the main journals are 15¼″ in diameter and 30″ long, except the forward journal, which is 24″ long. The cranks are counterbalanced.

The bed-plate is made in two parts and is bolted up to the condenser. This latter is in two pieces, and contains 1,492 tubes ⅝″ in diameter and 14 feet long, the surface exposed being thus 4,786 square feet. The water from one circulating-pump passes through them

three times and from the other twice. The pumps are worked from the main cross-heads through wrought-iron levers, as shown. Each air- and circulating-pump is cast separately and bolted to the condenser. A feed- and bilge-pump are bolted to each air-pump. The latter are 26″ in diameter, the circulating-pumps are 18″ in diameter, and the feed- and bilge-pumps are each 6″. The stroke of all is 26″.

A vertical turning-engine is bolted to the side of the condenser and gears into a worm-wheel fastened to the intermediate shaft-coupling between the two cylinders. The propeller-shaft is $15\frac{1}{2}$″ in diameter and is sheathed in the stern-pipe. The propeller is four-bladed, with the blades cast separately and bolted to the bars; the diameter is 17 feet and the pitch 24 feet.

Figure 3 exhibits an indicator diagram taken during the second trip of one of these steamers (the "Ohio"), and under the following conditions:

Pressure of steam in boilers	pounds..	60
Pressure of steam in receiver	do....	1.5
Vacuum in condenser	inches..	25.5
Revolution of engines per minute		60
Temperature of water in hot-well	degrees..	130
Steam cut off at 19″ in the high-pressure cylinder.		
Indicated horse-power in high-pressure cylinder		1,237.44
Indicated horse-power in low-pressure cylinder		740.1
Total		1,977.54

The running of the "Ohio" during the voyage from Queenstown to Breakwater, when the above diagrams were taken, was as follows:

Date.	Knots run by screw.	Knots run by observation.	Running time.	Remarks.
1873.			h. m.	
October 17	246.8	226.0	18 59	
October 18	323.8	280.7	24 23	
October 19	338.5	322.0	24 15	
October 20	335.7	294.0	24 23	
October 21	331.0	(*)	24 0	15 minutes' detention.
October 22	341.5	(*)	24 24	
October 23	336.7	946 in 3 days.	23 43	18 minutes' detention.
October 24	339.5	333.7	24 22	
October 25	343.2	321.0	24 21	
October 26	142.0	140.0	10 30	
Total	3,075.7	2,863.4	9d 7h 20m	

* No observation.

The slip of the screw amounted to 212.3 knots, or 6.8 per cent., while the average speed was 12.8 knots. The weather was calm.

That the performance of the engines we have described has been most satisfactory is proved by the great regularity of the passages made by the vessels to which they are fitted, while their workmanship and general finish well deserve praise.

ENGINES OF NEW ENGLAND STEAMERS.

Of the engines of steamers of Class I the greater number are beam-engines with surface-condensers. There are 10 simple direct-acting engines used in pairs. There is one compound engine 24 and 54 inches by 4 feet. Considering the high-pressure cylinder in this engine, we may say for all that the ratio of stroke to diameter is from 2 to 3 in 15 engines, $1\frac{1}{2}$ to 2 in 13 engines, 1 to $1\frac{1}{2}$ in 5 engines, and 1 or less in 16 engines. The "Bristol" and the "Providence," of the Fall River line, have each cylinders 110 inches by 12 feet, and the "Rhode Island" and the "Massachusetts" have each cylinders 90 inches by 14 feet. The boats having direct-acting vertical engines are almost without exception freight-boats, coasting to New York and southward. Their cylinders range from 62 by 48 inches (stroke) to 44 by 36 inches (stroke). The beam-engines are low-pressure, the "Bristol" carrying a maximum boiler-pressure of only 25 pounds.

The "Electra" and the "Galatea", each of 1566.70 tons, and built in 1864, are stated to have been the first high-speeded propellers used on Long Island Sound. The "Galatea" is classed as an inland passenger and the "Electra" as a freight boat. The "Electra" is 232 feet long, 40.3 feet broad, 15.3 feet deep, and has two condensing-engines, each 3 feet 8 inches diameter by 3 feet stroke.

The "Decatur H. Miller", 2296.14 tons, plying between Baltimore and Boston, has two compound engines; diameters of cylinders, 2 feet and 4 feet 6 inches; length of stroke, 4 feet. These engines are of the steeple type, the high-pressure being placed above the low-pressure cylinder; an arrangement similar to that illustrated in the engines of the "Buffalo" and the "Chicago", of the Western Transportation line, but not usual in the Atlantic district. This arrangement of compound engines is also approved in the most modern English practice, but the great majority of compound engines have the cylinders side by side, fore and aft. In the engines of the "Decatur H. Miller" the cranks are set at quarter angles.

In Class II there are no non-condensing engines, nor are there any paired engines, all being simple non-condensing engines either of the beam or direct-acting types. In ferry service in the Boston district there are several examples of direct-acting inclined engines, cylinders 40 inches diameter by 9 feet stroke. The rarity of horizontal engines upon New England steamers is in marked contrast with their common employment upon the bays and rivers of the Pacific coast. Of 29 engines, the ratio of stroke to diameter is from 3 to 4 in 3 engines, 2 to 3 in 17 engines, 1 to 1½ in 1 engine, and 1 or less in 9 engines.

In Class III there are 10 non-condensing engines, the rest being generally provided with surface-condensers, but sometimes with jet or outside-pipe condensers. Of the non-condensing engines, there are two pairs of horizontal engines, one direct-acting inclined and one beam-engine. There is one compound engine 8 and 16 inches by 16 inches stroke. Twenty-four engines are used in pairs. Of 84 engines, the ratio of stroke to diameter of cylinders is over 3 in 9 engines, between 2 and 3 in 29, between 1½ and 2 in 2 engines, between 1 and 1½ in 19 engines, and 1 or less in 25 engines. In 22 engines the diameter equals the stroke.

In Class IV, about one-fourth of the engines are non-condensing. Of the condensing-engines a large proportion have condensers of the kind known as keel or outside-pipe condensers. Fourteen engines are used in pairs, and out of 95, 25 are of the so-called "square" type, the stroke and diameter of cylinders being equal. Ratios of stroke to diameter 2 to 3 in 12, 1½ to 2 in 4, 1 to 1½ in 43, and 1 or less in 36 engines. The diameters and strokes are equal or nearly equal in 80 per cent. of the engines. The engines are nearly all vertical direct-acting or vertical back-acting; beam, horizontal, and inclined engines being the exception. The change of engines from long-stroke beam to short-stroke direct-acting engines accompanies a change in the method of propulsion from side-wheels to screws.

In Class V, nearly half of the engines are non-condensing. There are a few horizontal engines, but the vertical direct-acting and back-acting types are the rule. The ratio of stroke to diameter in cylinders is between 2 and 3 in 3 engines, between 1½ and 2 in 12, 1 and 1½ in 27, and 1 or less in 62 engines. Eighteen engines are used in pairs.

In Class VI, 10 out of 117 engines are compound. Eight of these have the cylinder dimensions 3½ and 6 inches by 7 inches stroke. The ratio of stroke to diameter of cylinders is between 2 and 3 in 1 engine, 1½ and 2 in 24, 1 and 1½ in 52, and 1 or less in 58. This considers only the high-pressure cylinder of compound engines. There is one oscillating-engine, an unusual type in America.

In 1859, the "Dawn", a small propeller, commenced running with a rotary engine, stated to be the first used in the merchant service. After two years' trial it was displaced by a simple cylinder-engine (*Nautical Gazette*).

ENGINE OF THE SOUND STEAMER "PILGRIM".

This new steamer of the Fall River line, in the great magnitude of its machinery, furnishes so notable an example of American practice that it has been thought best to include its description in this report, although, not being launched until after the close of the census year, it does not appear in the tables of statistics. A side view of the arrangement of machinery is shown in the skeleton sketch, Fig. 6. This merely indicates the position of the principal parts: A A, the poppet-valves on one side; B, the steam-cylinder; C, the condenser; D, the air-pump, and E, the centrifugal circulating-pump. The frame is not shown, fixed bearings being indicated by heavy open circles. In Figures 4 and 5 we have in detail illustrations of the cylinder and valves with connections, a front view, and a side elevation in section.

The cylinder is 110 inches in diameter and 14 feet in stroke. It is the largest ever cast, the rough casting weighing 30 tons. The metal is 1¾ inches thick at the thinnest point, and the flanges are 2⅝ inches thick by 5¾ inches wide. The piston is of cast iron, plano-convex box form, with 12 ribs. The follower-bolts are of wrought-iron, with brass nuts screwed into the piston. The piston-rod is a foot in diameter, with a 17-inch head. It is driven in by a ram, and held by a nut a foot high. The piston-ring sections are jointed diagonally and connected by means of filling-blocks. There is a surface-condenser placed under the cylinder. This contains about 12,000 square feet of condensing-surface in ¾-inch seamless brass tubes, tinned inside and out. There are two circulating-pumps with independent engines, and the air-pump is 60 inches in diameter and 6 feet in stroke, with a reservoir above it (not shown in the skeleton sketch). There are also two copper bilge-pumps. The balanced poppet-valves are 24½ and 25½ inches in diameter, of cast iron, with 2½-inch steel valve-stems. The side pipes are 33½ inches in diameter. The scale of the large drawings of the cylinder is about ⅓ inch to the foot, or $\frac{1}{36}$. The shafts are 39 feet 5 inches long, and together weighed 81,200 pounds in the rough. The dimensions of the several steps or diameters are as follows:

Part.	Diameter.	Length.	Part.	Diameter.	Length.
	Inches.	*Inches.*		*Inches.*	*Inches.*
Crank	26½	24	Paddle-flange boss	28	20
Collar	32	6	Step	26 to 24	43
Main journal	26	29	Paddle-flange boss	28	20
Collar	32	6	Step	23 to 21	38
Step	26½	37	Paddle-flange boss	28	20
In gangway	26	148	Outboard journal	19	31
Spring-bearing	27	51			

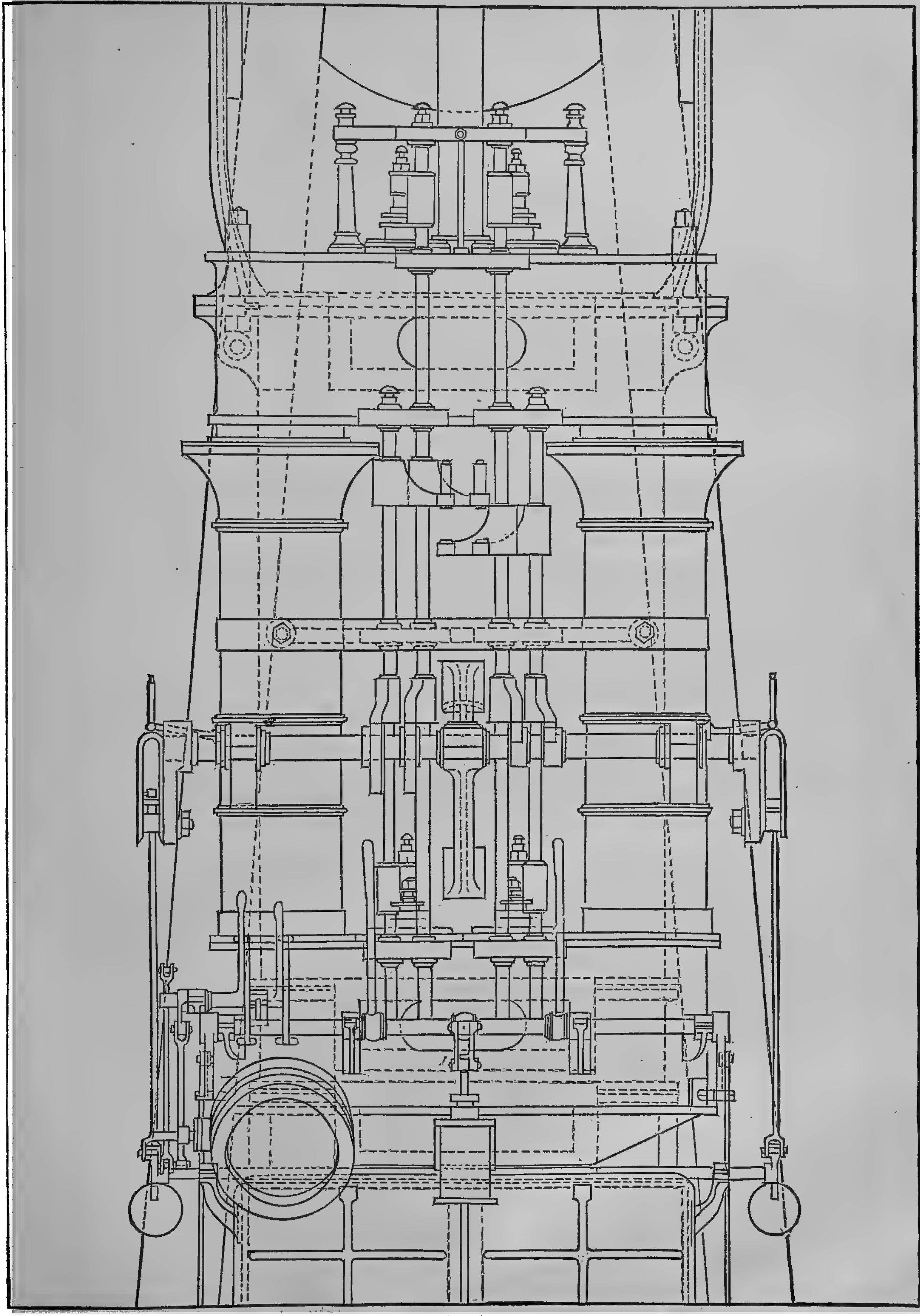


FIG. 4

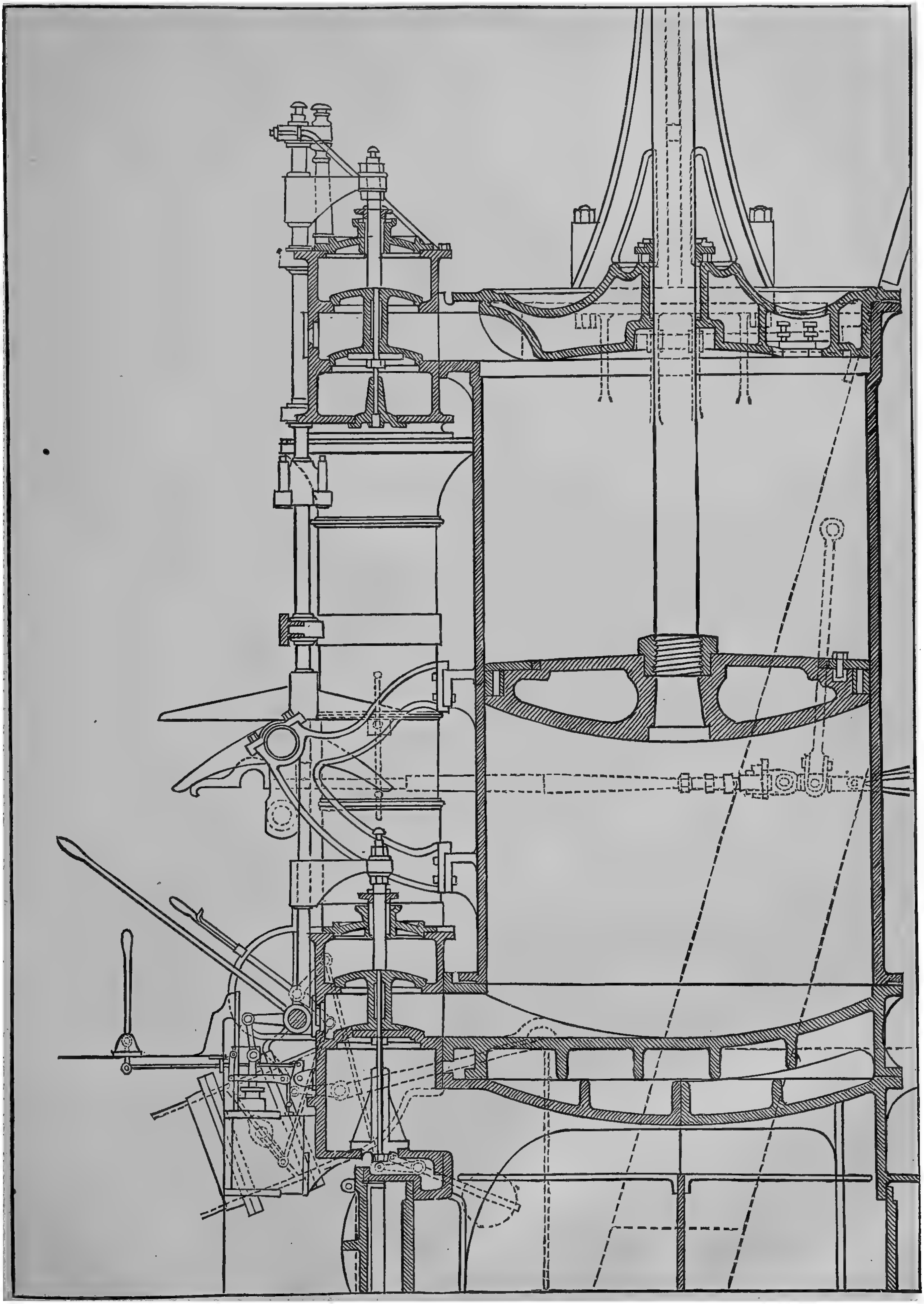


FIG. 5.

The wheels are 45 feet outside diameter, 13 feet face, buckets in two lengths, stepped. Each wheel has three cast-iron flanges 10′ 6″ in diameter, made in halves, and bolted together. Each flange has twenty-eight wrought-iron arms, each arm tapering from $8\frac{1}{2}''$ by $1\frac{3}{4}''$ at the flange to 5″ by $1\frac{1}{4}''$ at the outer rim. The outer rims are 6″ by $1\frac{1}{4}''$. Each wheel has twenty-eight oak buckets.

The cranks are 7 feet between centers; shaft-hub, $46\frac{1}{2}''$ diameter; pin-hub, 31″ diameter; shaft-hub, 24″ deep; pin-hub, 19″ deep; arm tapered from 17″ to 13″ in depth, 29″ to 21″ in width. The cranks were shrunk upon the $25\frac{1}{2}''$ shafts, with an allowance of $\frac{3}{128}$ for shrinking. The crank-pins are tapered from 17″ to $15\frac{1}{2}''$ diameter in the

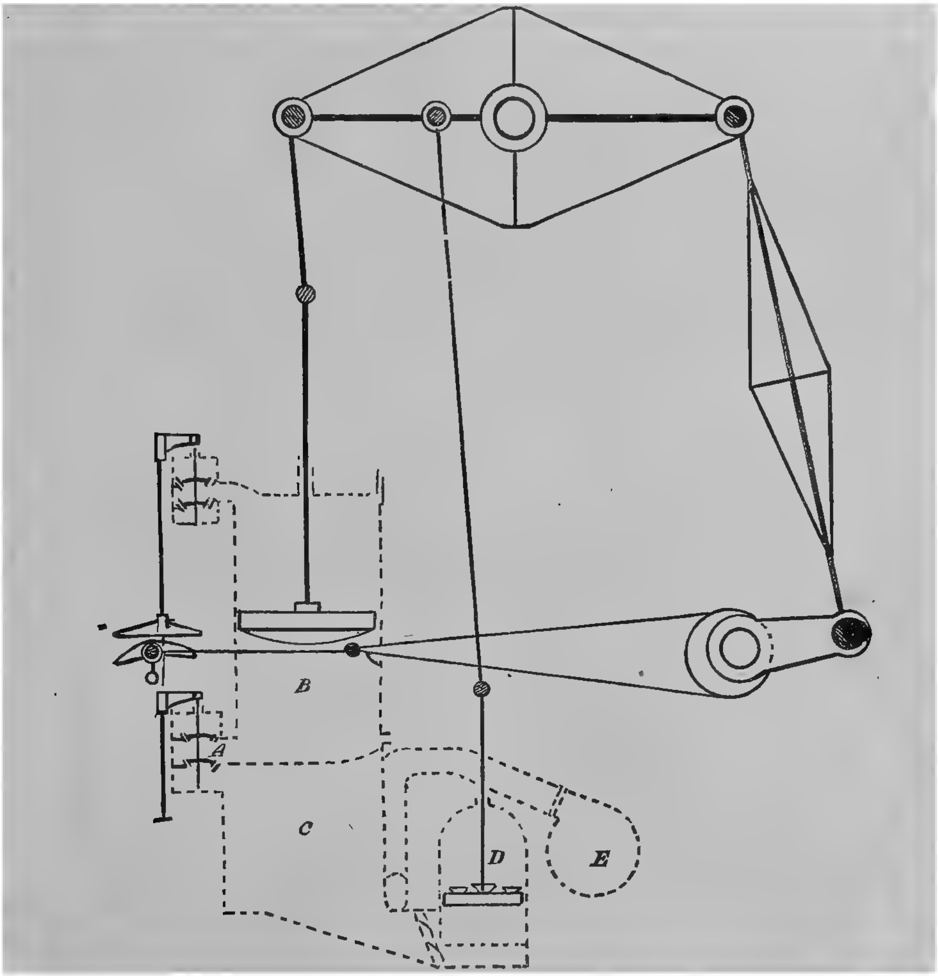


Fig. 6.

pin-hub, and are secured by a 6″ by $2\frac{1}{2}''$ key in one crank and by four brass chock-blocks bolted to the pin in the other. These chock-blocks allow some freedom of movement between the two shafts, and serve the same purpose as a drag-link. The connecting-rod is 33′ 9″ between centers, and the largest ever constructed; journals, 17″ by 23″ and $11\frac{1}{2}''$ by 12″; yoke, $18\frac{1}{2}''$ clear; $9\frac{1}{2}''$ by $12\frac{1}{2}''$ arms; upper neck of rod $11\frac{1}{2}''$, lower neck $12\frac{1}{2}''$ diameter; center band, $15\frac{3}{4}''$ diameter, with 3″ diameter struts set out 27″ from center of rod on either side, and with two $2\frac{1}{2}''$ diameter truss-rods. The main key is 57″ long, and tapers from 6″ to 3″. The forked end is forged solid, and the weight of the whole forging in the rough was over 13 tons. The maximum strain possible upon the smallest section of the rod is stated at considerably less than 5,000 pounds per square inch.

The walking-beam of the "Pilgrim" is an immense construction, 28′ 10″ center to center of pins, and 31′ 2″ long over all. It is the largest ever put into a steamer. The strap is 14′ 6″ from top to bottom at the center, and weighs 26,800 pounds, being made in two parts, and, each being bent in the middle, they are welded together at the ends. The value of the rough strap was $5,300. The beam center is a green sand casting, weighing 28,000 pounds, and is fastened to the main shaft by smaller straps passing over the latter and keyed through the casting and by keys between the beam center and the main strap, nine at each end, four at the top, and four at the bottom. The center pin is 7′ 6″ long, with 18″ diameter by 22″ long journals. The end pins are 3′ 5″ long, and have $11\frac{1}{2}''$ diameter bearings. The center pin is secured by 12 and the end pins each by 8 keys, and the hub is re-enforced by

two wrought-iron draw-bands 3″ square in section. The keys between strap and center are 3″ by 1″ at ends, 2″ by 1″ at top and bottom. The center pin keys are 3″ by 1″ in section and 3 feet long. Under a pressure of 40 pounds per square inch in the cylinder the main center will have a pressure of about 950 pounds per square inch, the speed of rubbing surface being 24 feet a minute. The end pins will have a pressure of over 1,300 pounds per square inch and a rubbing speed of 15 feet a minute. The foregoing data are derived mainly from recent numbers of the journal *Mechanics*, in which the details of construction of this great engineering work have been very fully discussed.

SMALL YACHT ENGINES.

These are in most cases inverted-cylinder direct-acting engines, accompanied by vertical tubular boilers. They are similar in type to many small portable and semi-portable engines used in light manufacturing work, both classes of engines being made by many manufacturers with similar patterns for the principal parts. The yacht-engines differ from the small manufacturing engines principally in dispensing with the throttle-valve, governor, governor-pulley, and fly-wheel, and substituting a simple link motion for reversing the engine and determining the point of cut-off. A starting-wheel is also necessary, and the feed-pump is operated by an eccentric upon the main shaft. The valves are sometimes slide and sometimes rotary. The following data are given of the reversing-engines for yachts and tug-boats, as built by the Fitchburg Steam Engine Company, of Fitchburg, Massachusetts, with the corresponding data of suitable hulls and boilers. The engines are of a design similar to the Haskins portable engine adapted for marine service, and are made with interchangeable parts to standard gauges and templates:

Engine-cylinder.	Maker's nominal horse-power.	Shaft, length.	Shaft, diameter.	Screw, diameter.	Boilers,* diameter.	Boilers, height.	Heating-surface.	Weight, engine, screw, and shaft.	Weight, boiler.	Hull, tonnage, carpenters' measurement.	Hull, length, feet.	Hull, breadth, feet.	Hull, draft, feet.
Inches.		*Feet.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Sq. feet.*	*Pounds.*	*Pounds.*		*Feet.*	*Feet.*	*Feet.*
3 by 4	2	12	1¼	24	28	45	60	380	1,100	4	26	5½	2¼
4 by 4	4	15	1½	26	28	48	90	500	1,200	6	32	6⅓	2½
5 by 5	5	16	1¾	30	32	56	120	700	1,300	9	38	7⅛	3⅛
6 by 6	6	17	2	32	32	58	150	1,000	1,600	12	40	7½	3⅓
6½ by 6½	8	18	2⅛	36	36	58	170	1,100	2,200	14	45	8¼	3½
7 by 7	10	18	2¼	39	36	66	200	1,350	2,650	16	50	9	3½
8 by 8	12	20	2½	42	42	66	230	1,800	3,000	21	55	9½	3¾

a The boilers are of steel.

This table affords scope for a number of comparisons relative to the economy of material in the machinery of large and small vessels. Large marine engines are not made in lots, nor with interchangeable parts, nor in such numbers as to make trade schedules necessary, but we may easily cite such data as will suffice to indicate general conditions and exhibit some striking contrasts.

A large propeller, having about 55 cubic feet of cylinder capacity and an 18″ shaft 90 feet long: As compared with the machinery of the 8″ by 8″ yacht-engine, we find that while the cylinder capacity is 242 times greater, the section of shaft is about 52 times greater, and its cubical contents are about 233 times greater. With shaft $7\frac{7}{10}$ times as great in diameter and 4½ times as long, the screw-propeller is less than 4 times the diameter. The 8″ by 8″ yacht-engine has one 42″ by 66″ vertical boiler, while the 48″ by 72″ engine of the "Vera Cruz" has two 156″ by 238″ vertical boilers. With the boiler volume about 100 times as great the cylinder volume is about 330 times as great, and the heating surface being 230 and 5,290 square feet respectively, the heating surface is only 23 times as great in the large boilers as in the small ones. Comparing the steamers, the larger is nearly 5 times as long and nearly 4 times as broad as the smaller, and the registered tonnage would be about 100 times as great.

An example of a somewhat larger yacht than those tabulated is as follows: Length, 77′ 6″ on water line and 84 feet on deck, 15 feet breadth of beam, 6 feet deep, drawing 4′ 6″ water, engines 10″ by 10″, supplied with steam at 125 pounds, and making 200 revolutions a minute. The propellers are 5 feet diameter and 8 feet pitch. A yacht of 450 tons has a propeller 9 feet in diameter and 13 feet long, and a 10-inch shaft.

BACK-ACTING ENGINES.

For small propellers, steam yachts and launches, the back acting engine is a type introduced within the past ten years in considerable numbers in New England and upon the Atlantic seaboard. These engines may be conveniently employed in sets of two or three or more, set closely together, as shown in the illustration (Fig. 7). The figure exhibits the arrangement of link and reversing motions and other details. The main cross-head ends of the connecting-rods are seen to be yoked or divided into two parts, which pass up on either side of the cylinders, the cross-heads moving in slide-guides in neat frames or housings above the cylinders. It would be hard to design a more compact arrangement. Its most obvious merit consists in the lowering of the frame which supports the

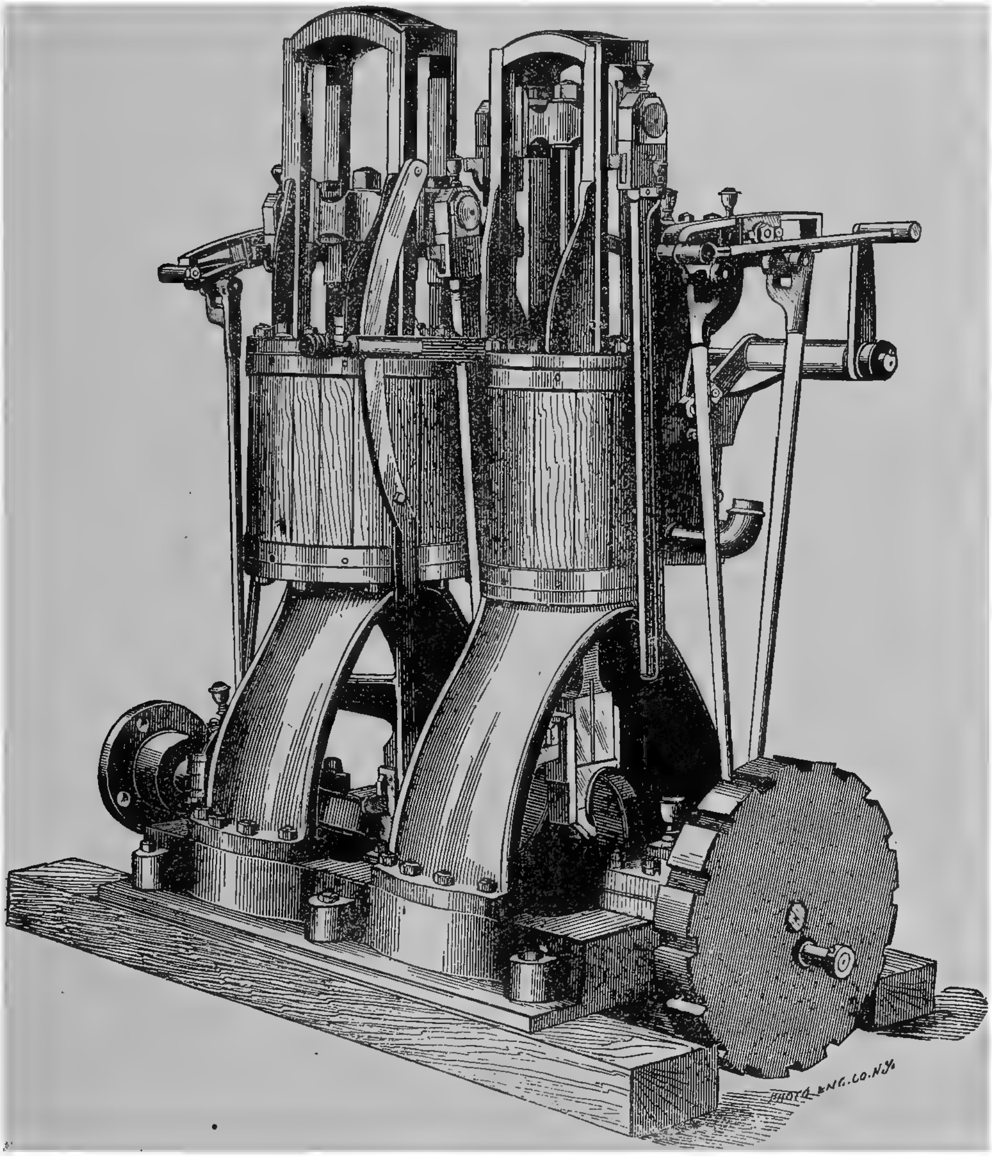


FIG. 7.

cylinders, making a much lighter and more stable construction than can be had with the inverted cylinders and permitting a greater length of connecting-rod, which in the engine shown is about four times the length of stroke. With long connecting-rods there is of course less wear and friction upon the slides. The piston-rods passing through the upper cylinder-head makes the stuffing-boxes easily accessible, and the larger area of the piston being below, the pressure upon the space occupied by the piston-rod helps to balance the weight of the reciprocating parts. The engines illustrated are made by James H. Paine, of Boston. They may be used in pairs simply or compounded, with a saving of fuel (stated at 25 to 35 per cent.) over the simple engine. Examples of steamers with back-acting engines: The "Adelita", 15.03 tons (49.4 feet long, 53 feet over all, and 10.2 feet beam), has two 7″ by 7″ engines, with keel-condenser, and 5″ by 4½″ air-pump; the "Psyche" (72 feet long, 12 feet beam) has two cylinders 9″ and 15″ by 9″, placed as a pair, with cranks at right angles, and constituting one compound engine.

SMALL COMPOUND ENGINES.

A popular form of compound engine for small boats is that used in connection with the Herreshoff coil-boiler. This type of engine is illustrated in Fig. 8, and the following description of the engine and screw, as applied in connection with a coil-boiler to the steam yacht "Leila", is taken from a report of the United States Navy Department. The "Leila" is of 37.27 tons displacement; length of deck, 100 feet; breadth of deck, 15′ 4″; depth of hull, 5′ 10″; draft (greatest) at stern, 3′ 1½″:

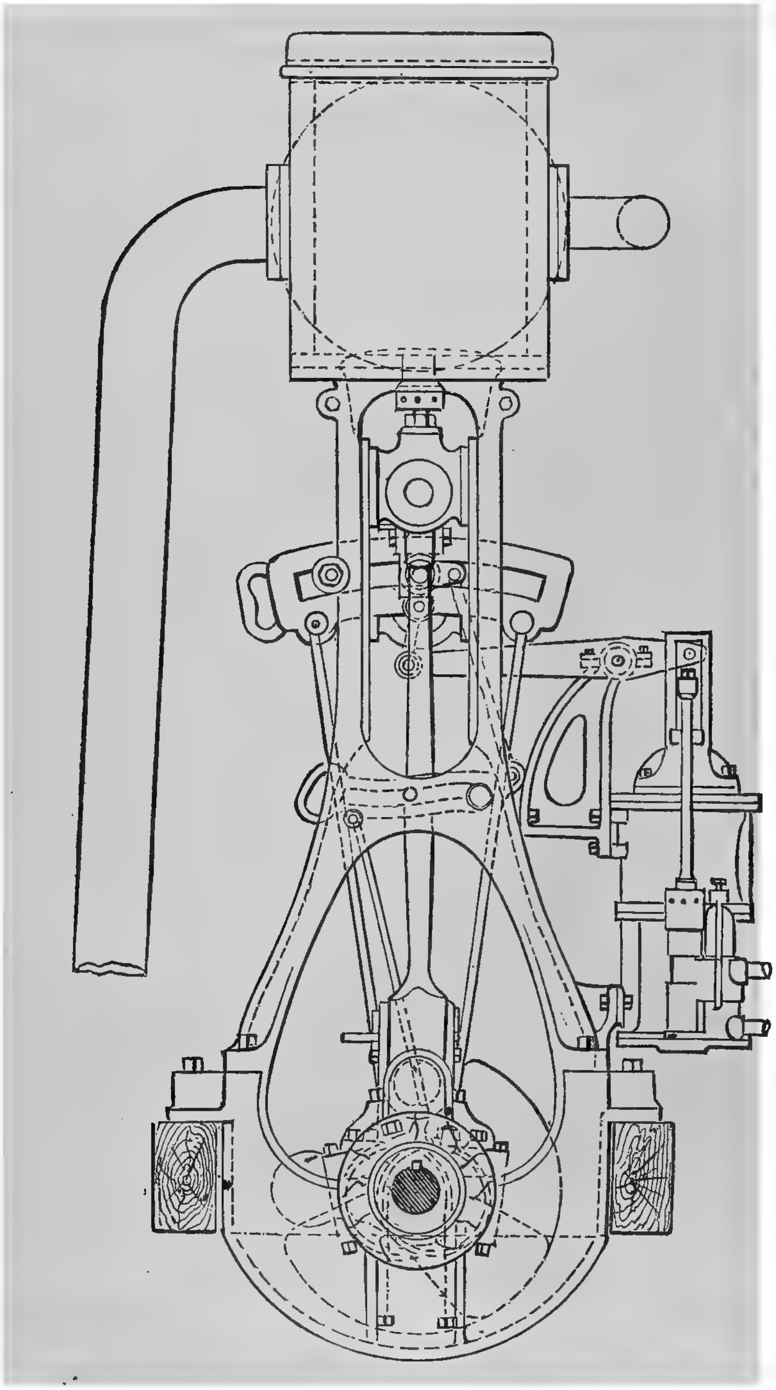


FIG. 8.

There is one compound condensing-engine with vertical cylinders placed side by side above the crank-shaft and having their axes in the vertical plane passing through its axis. The cylinders are direct-acting, the outer end of the piston-rod being secured into a cross-head working between guides in the engine-frame, while the connecting-rod lies in direct extension between the cross-head journal and the crank-pin journal.

The forward or small cylinder operates a lever, which works the air-pump, the feed-pump, and the circulating-pump, all of which are vertical, single-acting, and have the same stroke of piston. The axes of these three pumps are in the same vertical plane, which is parallel to the vertical plane passing through the axis of the crank-shaft. The feed-pump and the circulating-pump are plunger-pumps, with brass receiving- and delivering-valves. The air-pump is a lifting-pump, without a foot-valve; its receiving-valve is brass, circular, and placed in the piston; its delivering-valve is also of brass, and discharges into an open-topped hot-well or reservoir placed above the outboard water-line, the top of the air-pump being closed. The air-pump piston is not packed, but ground to a metallic fit in the brass barrel.

The cylinders are separated to allow the valve-chests to be placed between them, with sufficient additional space for the removal of their covers. The valves of each cylinder are a plain three-ported slide with a slide cut-off on its back; these valves are not counter-balanced, but work with the full steam-pressure on their backs. The three-ported slides or steam-valves are operated each by a Stephenson link and two eccentrics, which serve as a reversing gear. The cut-off valves are each operated by an eccentric. The three eccentrics of each cylinder are immediately beneath its valve-chest. The cut-off valve of the small cylinder is adjustable; that of the large cylinder is fixed to cut off at about one-third of the stroke of the piston from the commencement.

The engine-frames, four in number, are each in a single casting and bolted to a bed-plate, which is also a single casting extending under the entire length and breadth of the engine. The cross-head guides are on these frames, to the top of which the cylinders are bolted. The bed-plate has a semicircular bottom, and its side flanges are bolted to side keelsons. The crank-shaft has three bearings or pillow-blocks cast in the bed-plate, the forward crank being overhung.

The engine works with surface condensation. The surface-condenser is composed of a single copper pipe placed on the outside of the vessel, beneath the water, and just about at the garboard strake. This pipe commences on one side of the vessel abreast of the after or large cylinder, extends to and around the stern-post, and thence along the opposite side of the vessel until abreast of the air-pump and forward cylinder. The diameter of the pipe continuously decreases from the end at which it receives the exhaust-steam from the large cylinder to the end at which it delivers the water of condensation and the uncondensed vapor and air into the air-pump, whence they are thrown into the hot-well, from which the feed-pump forces the water of condensation into the top of the boiler-coil, where it is revaporized, and the steam, passing first into the small cylinder and thence into the large one, is finally exhausted into the condensing-tube. It is essential for satisfactory working that the delivering end of this tube should not exceed one-half the diameter of its receiving end; for if a larger diameter be given to the delivering end, a part of the exhaust steam will pass directly to the air-pump over the water of condensation in the tube. The delivering end of the tube must be small enough to remain completely filled with water for the exclusion of the steam from the pump.

The after main pillow-block serves also as the thrust pillow-block, the after journal of the crank-shaft being made with the necessary thrust-rings upon it.

The cylinders and their valve-chests, including covers of both, are incased with polished brass, between which and the iron are air spaces.

The following are the principal dimensions of the engine:

Number of cylinders		2
Diameter of the small cylinder	inches	9
Diameter of the piston-rod of the small cylinder	inches	$1\frac{5}{8}$
Net area of the piston of the small cylinder	square inches	62.58045
Stroke of the piston of the small cylinder	inches	18
Space displacement of the piston of the small cylinder, per stroke	cubic foot	0.65188
Space in clearance, and steam passage at one end of small cylinder	cubic foot	0.05752
Fraction which the space in clearance and steam passage at one end of the small cylinder is of the space displacement of the piston of the small cylinder, per stroke		0.08824
Length of steam-port of small cylinder	inches	7.5
Breadth of steam-port of small cylinder	inches	$1\frac{1}{16}$
Area of steam-port of small cylinder	square inches	7.97
Length of exhaust-port of small cylinder	inches	7.5
Breadth of exhaust-port of small cylinder	inches	1.75
Area of exhaust-port of small cylinder	square inches	13.125
Clearance of piston of small cylinder	inch	$\frac{3}{16}$
Aggregate area of the inner cylindrical surface of the small cylinder, of its two steam passages, of its two ends, of the two faces of its piston, and of half its piston-rod	square inches	690
Diameter of the large cylinder	inches	16
Diameter of the piston-rod of the large cylinder	inches	$1\frac{5}{8}$
Net area of the piston of the large cylinder	square inches	200.02545
Stroke of the piston of the large cylinder	inches	18
Space displacement of the piston of the large cylinder, per stroke	cubic feet	2.08360
Space in clearance and steam passage at one end of large cylinder	cubic foot	0.14066
Fraction which the space in clearance and steam passage at one end of the large cylinder is of the space displacement of the piston of the large cylinder, per stroke		0.06751
Length of steam-port of large cylinder	inches	13
Breadth of steam-port of large cylinder	inches	$1\frac{7}{16}$
Area of steam-port of large cylinder	square inches	18.69
Length of exhaust-port of large cylinder	inches	13
Breadth of exhaust-port of large cylinder	inches	2.5
Area of exhaust-port of large cylinder	square inches	32.5
Clearance of piston of large cylinder	inch	$\frac{3}{16}$
Aggregate area of the inner cylindrical surface of the large cylinder, of its two steam passages, of its two ends, of the two faces of its piston, and of half its piston-rod	square inches	1,515
Diameter of the air-pump	inches	7
Diameter of the piston-rod of the air-pump	inches	$1\frac{1}{2}$
Stroke of the piston of the air-pump	inches	6
Space displacement of the air-pump piston, per stroke	cubic foot	0.1275
Diameter of the plunger of the feed-pump	inches	$1\frac{1}{2}$
Stroke of the plunger of the feed-pump	inches	6
Space displacement of the plunger of the feed-pump, per stroke	cubic foot	0.0061358
Diameter of the plunger of the circulating-pump	inches	$1\frac{1}{8}$
Stroke of the plunger of the circulating-pump	inches	6
Space displacement of the plunger of the circulating-pump, per stroke	cubic foot	0.0034515
Width of all eccentric straps	inches	$2\frac{1}{8}$
Depth of the packing-ring in both steam-pistons	inch	$\frac{7}{8}$
Length of the condensing-pipe	feet	53
Inside diameter of condensing-pipe at exhaust-steam end	inches	5
Continuously decreasing to inside diameter at air-pump end of	inches	2
Thickness of the metal of the condensing-pipe (copper)	inch	$\frac{1}{16}$
Exterior surface of the condensing-pipe	square feet	50.2983
Interior surface of the condensing-pipe	square feet	48.5639
Length of the connecting-rods between centers	inches	$49\frac{1}{2}$
Diameter of the necks of the connecting-rods	inches	$1\frac{9}{16}$
Diameter of cross-head journals	inches	$2\frac{1}{4}$
Length of cross-head journals	inches	$3\frac{1}{4}$
Diameter of forward crank-pin journal (overhung)	inches	$2\frac{1}{4}$
Length of forward crank-pin journal	inches	$4\frac{1}{2}$
Diameter of after crank-pin journal	inches	$3\frac{7}{8}$
Length of after crank-pin journal	inches	$3\frac{1}{2}$
Number of crank-shaft journals		3
Diameter of crank-shaft journals	inches	$3\frac{7}{8}$
Length of crank-shaft journals	inches	8
Diameter of screw-shaft inside of brass casing	inches	$3\frac{7}{8}$
Number of thrust-rings on crank-shaft		5
Breadth of each thrust-ring	inch	$\frac{1}{2}$
Projection of each thrust-ring from shaft	inch	$\frac{9}{16}$
Length in the vessel occupied by the engine	inches	66
Breadth in the vessel occupied by the engine	inches	48
Height of engine above center of crank-shaft	inches	96
Ratio of the space displacement of the piston of the large cylinder, per stroke, to that of the small cylinder		3.196293

SCREW.—There is one true screw of brass with uniform pitch and four blades equispaced around the axis. The blades are at right angles to the axis; their forward and after edges when viewed in projection on a plane parallel to the axis are parallel. The outboard end of the screw-shaft is cased with brass and supported by a lignum-vitæ bearing.

The following are the dimensions of the screw:

Diameter	feet..	$4\frac{7}{12}$
Diameter of the hub	inches..	7
Pitch (uniform)	feet..	8
Number of blades		4
Length of the screw (uniform from hub to periphery)	inches..	$9\frac{3}{4}$
Fraction of the pitch used		0.40625
Heloicoidal area of the screw-blades	square feet..	9.4564
Projected area of the screw-blades on a plane at right-angles to axis	square feet..	6.5941

The single view of the engine presented in Fig. 8 does not fully explain its arrangement, but a clear idea of this may be given in a few words. The view is looking forward showing the large cylinder, back of which is the small one. The main exhaust-pipe appears at the left and the exhaust-pipe from the high-pressure cylinder leading to the large cylinder appears at the right of the cylinders. Each cylinder has a main and a cut-off slide-valve, and the high-pressure cylinder a variable cut-off. The valve-chests are placed between the cylinders instead of on the opposite sides of them, as in the large engines of the American Steamship Company's vessels. There are, in all, six eccentrics, and, to avoid confusion with the details of cranks and pinch-wheel, not all of their details are dotted in upon the view shown. The pumps are worked by the usual beam arrangement, the air-pump being in line with and opposite the high-pressure cylinder, and the feed- and circulating-pumps on either side of it, operated from the same cross-head. The arrangement of the engine is compact and workmanlike, and, although so small that the links may, as shown, be shifted by handles, it is seen to embody all the essential features of the largest compound engines.

ENGINES OF ALBANY STEAMERS.

Class I: All the engines of this class are beam condensing engines of 12′ stroke, diameters of cylinders ranging from 4′ 8″ to 6′. The general arrangement of these engines is similar to that of the steamer Pilgrim, of which a special account is given.

Class II: There are 14 engines, all used singly, and all condensing. Twelve are beam-engines driving side. wheels. The swift steamer "Mary Powell" is a familiar example of a boat with this style of engine. The two remaining engines are short-stroke direct-acting engines, driving the screw-propellers of the boats "Thomas McManus" and "Andrew Hardee". These are passenger-boats plying from New York to Coxsackie and Poughkeepsie respectively, and are thus in the same class of service as most of the beam-engine boats. But they represent no new innovation in the service, the boats being 15 or 20 years old, while many of the side-wheel boats are of more recent build. The "Mary Powell" has a 6′ by 12′ engine. The "Armenia," a side-wheel steamer built in 1847, and now plying between New York and Albany, has a 40-inch by 14 foot engine, an unusually long stroke for the bore.

Class III: Of 31 engines, 2 are inclined condensing (a ferry-boat type), 1 vertical condensing, 1 vertical non-condensing, 26 beam condensing, and 1 beam non-condensing. Some of the beam engines are as small as 2′ or 3′ in diameter of cylinder by 5′ or 6′ stroke. These are for the most part upon the Hudson-river ferry and short-route boats.

Class IV: There are 20 engines, 3 compound, 5 beam condensing, 8 short-stroke non-condensing, 2 beam non-condensing, 1 inclined non-condensing, and 1 vertical non-condensing. The "Riverside," plying between Rondout and Sleightville, is a small paddle-wheel boat driven by two 6″ by 15″ engines. Twelve out of 19 of the boats are screw-propellers.

Class V: Nearly all of the boats are river tugs with vertical non-condensing engines. The only exceptions are the tug "John S. Ide," with a 2′ by 4′ beam-engine, the tug "John S. Winslow," with a 17″ by 20″ condensing-engine, the tug "Charles P. Grout," with a $22\frac{1}{4}$″ by 36″ inclined condensing-engine, and the yacht "Dashaway," 28.56 tons, with two 9″ and 16″ by 9″ stroke compound engines.

Class VI: The yacht "Presto," 16.68 tons, has one compound engine 5″ and 15″ by 6″ stroke. The tug-boat "May Flower" has a 14″ by 12″ stroke vertical condensing-engine. The small ferry-boats "Wm. H. Frear" and "Wm. C. Winne" have each a pair of horizontal engines, dimensions 7″ by 12″ for the former and 5″ by $9\frac{1}{2}$″ for the latter boat. These are paddle-wheel steamers. But 63 out of 69 engines are of the simple vertical non-condensing type.

It may be noted that there are in this inspection district only 5 pairs of engines, and these are upon comparatively small craft.

ENGINES OF NEW YORK STEAMERS.

Class I: Of 77 engines, 22 are beam-engines, driving side-wheels, and the remainder are direct-acting engines driving screws. All are condensing. The employment of compound engines is elsewhere specially considered. The compound engines are slide-valve engines, as are most engines of screw-propellers. The "Hudson," "New Orleans," "Knickerbocker," and "Louisiana," of the Cromwell line, are poppet-valve engines, which by their successful performance militate against the prejudice that poppet-valves are inapplicable to the high rotative speeds used in screw propulsion.

As typical steamers we may mention—

The excursion steamer "Plymouth Rock:" 1,810.16 tons; engines, 76″ by 12′; boiler-pressure allowed, 35 pounds.

The "Knickerbocker," of the Cromwell line: 1,642.48 tons; engines, 44″ by 6′; boiler-pressure allowed, 60 pounds.

The New York and Albany river-steamer "Drew:" 2,902.24 tons; engine, 81″ by 15′ (the engines of this steamer and the "Saint John" are among the longest-stroke engines in the world); boiler-pressure allowed, 35 pounds.

The transfer steamer "Maryland:" 1,093.03 tons; two engines, 40″ by 8′; boiler-pressure allowed, 32 pounds.

The ferry-boat "Plainfield:" 1,051.21 tons; one 53″ by 12′ engine; boiler-pressure allowed, 30 pounds.

The Old Dominion line steamer "Manhattan:" 1,525.19 tons; plying between New York and Richmond; one compound engine, 28″ and 53″ by 48″; boiler pressure allowed, 80 pounds.

The New York and Galveston steamer "Rio Grande:" 2,656.29 tons; one compound engine, 34″ and 60″ by 54″; boiler-pressure allowed, 80 pounds.

The New York and Charleston steamer "Morro Castle:" 1,713.61 tons; one 50″ by 5′ engine; boiler-pressure allowed, 50 pounds.

Class II: Of 90 engines in this class 85 are beam and inclined engines driving paddle-wheels, and 5 are short-stroke engines driving screw-propellers. The beam-engines are the prevailing type. The East river ferry-boats have inclined engines with Sickle's cut-off. The "Rockaway," 520.83 tons, plying to Hunter's Point, has one 44″ by 9′ engine, suction-condensing. All of the engines in this class are condensing-engines.

The inland passenger screw-propeller "Holmdel," 500.65 tons, has one 34″ by 34″ engine; boiler-pressure allowed, 35 pounds.

The Pavonia ferry-boat "Delaware," 985.88 tons, has one 50″ by 10′ engine; boiler-pressure allowed, 25 pounds.

With this we may compare the "Mary Powell," 983.57 tons, of the Albany district, one of the fastest boats in the world. This has one 6′ by 12′ engine; boiler-pressure allowed, 35 pounds. The power capacity in proportion to the tonnage is seen to be much greater in the latter steamboat.

Class III: Of 188 engines 123 may be considered as short- and 65 as long stroke engines, while 10 are compound to 178 simple, and 40 non-condensing to 148 condensing. Surface-condensers are the rule, but there are also jet, ejector, and outside-pipe condensers.

The "Relief," 338.18 tons, a coasting steamer, has two 26″ by 26″ engines with an ejector-condenser. The boiler pressure allowed is 45 pounds.

The freight-boat "Pioneer," a screw-propeller of 329.85 tons, has two horizontal engines 16″ by 3′; boiler-pressure allowed, 50 pounds.

There are several three-cylinder compound engines, the largest being upon the yacht "Polynia," but most of them are upon canal-boats plying between New York and Buffalo. The canal-boat "City of Troy," 124.16 tons, has one compound engine 5″, 14″, and 14″ by 14″ stroke; boiler pressure allowed, 100 pounds.

The "George U. Beale," 114.01 tons, coasting between Eastport and Sandy Hook, has one 22″ by 22″ engine with outside-pipe condenser; boiler-pressure allowed, 80 pounds.

Class IV: The types of engines are similar to those of the short-stroke engines of the preceding class. There are more non condensing engines, over half being non-condensing, and with the condensing-engines jet- and keel-condensers are most commonly used. The few compound engines are upon yachts and canal-boats. Simple short-stroke engines in which the bore equals the stroke outnumber all others, and of 152 engines there are only half a dozen of long stroke. These are used on small side-wheel boats, of which the "James A. Stevens," "Only Son," "George Birkbeck," and "Rattler" are examples familiarly known in New York harbor. The small ferry-boat "Surf," plying between Babylon, Long Island, and Fire Island, has a pair of oscillating engines driving side wheels. Non-condensing engines are employed not only on many of the harbor tugs but upon some coastwise vessels such as the fishing-boat "Eugene F. Price." Many of the inland passenger boats have condensers.

The fishing-boat "Eugene F. Price," 55.33 tons, has one 16″ by 18″ engine; boiler-pressure allowed, 75 pounds.

The ferry-boat "Surf," 64.48 tons, has two 13″ by 18″ oscillating engines; boiler-pressure allowed, 80 pounds.

The tug-boat "Rattler," 51.42 tons, has one 28″ by 8′ beam-engine, condensing; boiler-pressure allowed, 30 pounds.

The yacht "Fra Diavolo," 51.43 tons, has one compound engine 13″ and 16″ by 12″; boiler-pressure allowed, 100 pounds.

Class V: Of 149 engines about four-fifths are of the short-stroke non-condensing type. The compound engines and the surface-condensers are found mainly upon yachts and fishing-boats. Of the tug-boat engines the following examples are cited:

Name of tug.	Tonnage.	Engines.	Boiler-pressure allowed.
		Inches.	
Don Juan	45.86	20 by 20	65
Gorilla	44.90	18 by 16	70
Sadie E. Ellis	42.66	14 by 14	90
Frank Pidgeon	34.45	18 by 18	65
S. E. Babcock	33.49	18 by 18	80
Spray	32.15	$18\frac{1}{2}$ by 18	70
General George G. Meade	30.99	17 by 17	95
William Cramp	30.76	17 by 15	70
General William Cook	25.83	18 by 18	60
William H. Taylor	25.09	18 by 16	100

Class VI: In this class there are more yachts and relatively fewer tug-boats than in the preceding. There is in consequence a somewhat greater variety in the types of engines. There are more paired engines and relatively more compound and condensing engines. One boat, the tug "Sunbeam," 8.75 tons, has a Root engine, a peculiar form of engine in which one "cylinder" with its piston is placed within the piston of a larger "cylinder". The cylinders so-called are of rectangular section. The pistons moving at right angles, by their combined movement communicate a rotary motion to the shaft. The arrangement is ingenious and very compact, but subject to objection on other grounds.

Of 115 engines enumerated in this class only 38 have the diameter of cylinder equal to the stroke of piston, but scarcely any of them deviate more than an inch or two from this proportion.

POPPET-VALVE ENGINES FOR OCEAN SERVICE.

The most notable development in American marine engineering practice of the past decade has been the introduction of the poppet-valve engine into successful ocean service for screw propulsion. Mr. John Baird has designed these engines, and should be credited with the genius of departing from stereotyped models and making a successful application of novel principles. The poppet-valve was applied in the direct-acting engines of the New Orleans, Knickerbocker, and Hudson, of the Cromwell line. The steamship "Hudson" was built by Messrs. Pusey & Jones, of Wilmington, Delaware, in the space of six or seven months, being launched in the spring of 1874. The engine is simple, direct-acting, inverted, with poppet-valves, Sickel's cut-off, and surface-condenser. The dimensions of cylinder are 48″ diameter and 72″ stroke. There is one air-pump, 30″ in diameter by 18″ stroke, and there are two double-acting feed-pumps, each $5\frac{3}{4}$″ in diameter by 15″ stroke. There is an independent centrifugal circulating-pump, 5′ diameter of fan, and making 50 revolutions per minute.

The following dimensions are given of the steamer "Hudson:" Registered tonnage, 1,872.68; length on water-line, 280 feet (from aft side of inner stern-post to aft side of stern); width, 34 feet; draught as follows, first, with water in boilers and no coal; second, with 379 tons of coal on board:

Part.	First.	Second.
	Ft. in.	*Feet.*
Forward	6 2	10
Mean amidships	9 11	12
Aft	13 8	14

Gross depth of vessel, 23 feet; displacement, 2,100 tons with coal, 1,700 tons without coal.

The weight of material in the engine proper is as follows:

Part.	Pounds.
Iron forgings	108,613
Cast iron	246,998
Steel castings	1,433
Steel forgings	1,018
Angle iron	695
Sheet iron	607
Babbitt metal	1,118
Cast brass and copper	12,140
Copper pipes	4,005
	376,627

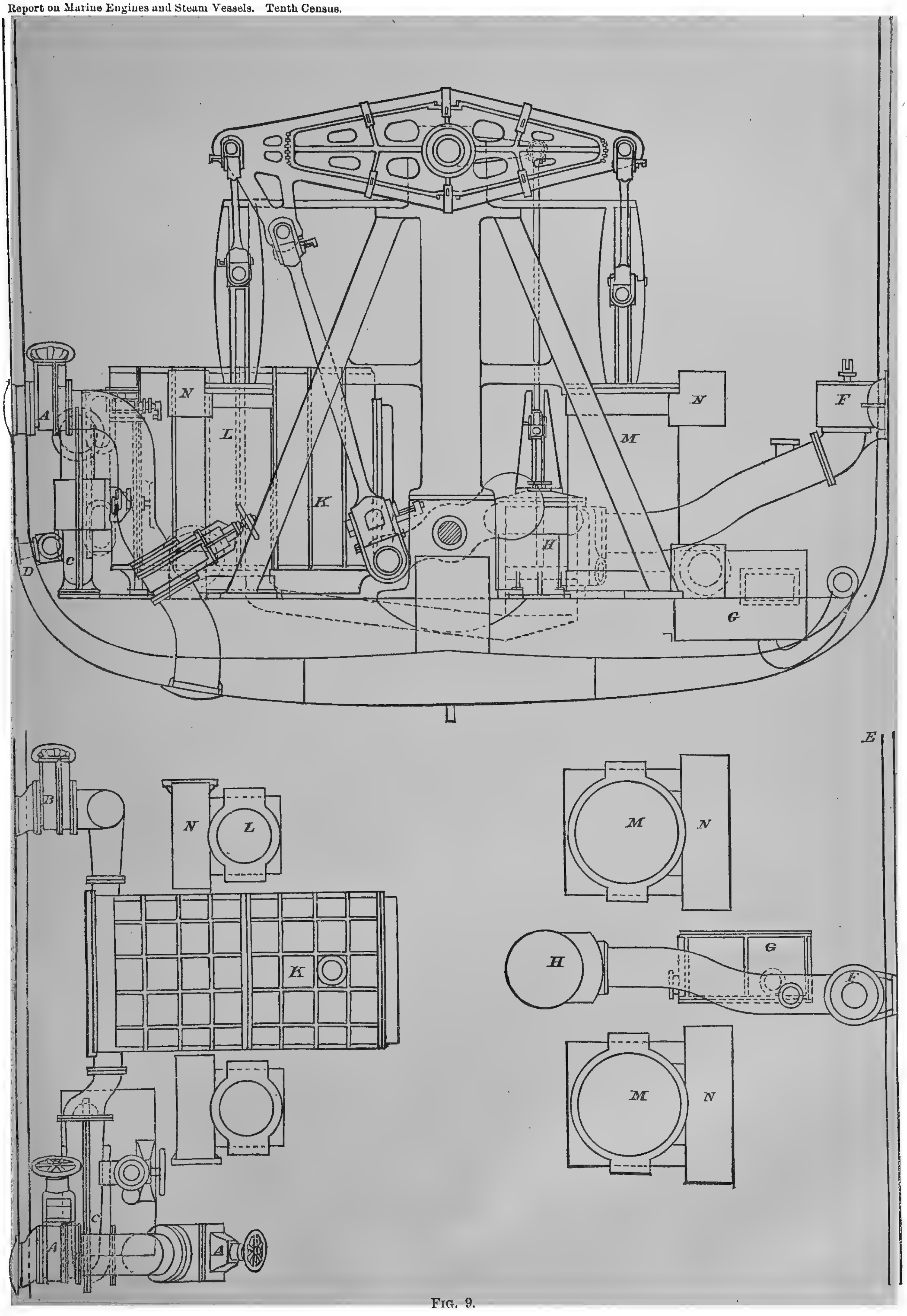


FIG. 9.

The condensing-surface is 3,271.66 square feet, measured as usual outside the tubes. The tubes are $\frac{5}{8}''$ diameter outside, being $\frac{1}{2}''$ inside.

The speed of the vessel is stated at 13 knots (not miles) an hour. The following brief is given of the captain's log in running from New York to New Orleans, the sails not being set during the voyage:

Time.	Average revolutions.	Boiler-pressure.	Knots run.
		Pounds.	
First day	$56\frac{1}{4}$	62	240
Second day	$60\frac{1}{4}$	73	281
Third day	$60\frac{1}{2}$	73	279
Fourth day	$60\frac{1}{8}$	74	294
Fifth day	$60\frac{11}{16}$	74	307
Sixth day (19 hours to bar)	$62\frac{1}{4}$	74	235
Total			1,636

On this trip the mean pressure shown by cards was $27\frac{1}{2}$ pounds per square inch; indicated horse-power, 1,131; piston speed as high as 750 feet per minute; coal burned per hour per square foot of grate, $13\frac{3}{4}$ pounds; coal per day, 29.76 tons; per indicated horse-power per hour, 2.19 pounds. This, however, does not give the best economy of the engines. It is stated in the London *Engineering* that a rating of coal per indicated horse-power of only 1.36 pounds has been attained, the engines of the "Hudson" developing upwards of 1,150 horse-power with 19 tons of anthracite in twenty-four hours, and the similar but smaller engines of the Knickerbocker developing upwards of 780 horse-power with 17 tons anthracite in twenty-four hours. The economy is equal to that of the best compound engines and exceeds that of many of them.

With the present practice in compound engines $1\frac{1}{2}$ to $2\frac{1}{4}$ pounds coal per indicated horse-power is consdered good economy, but over 3 pounds is considered an economical failure. The diagrams from the "Hudson" (Fig. 10) show very forcibly the peculiar operation of the engine as controlled by the valve movement, viz, an excellent expansion and no cushioning. The data for diagram No. 1 are: Date, November 13, 1874; revolutions, $62\frac{1}{2}$; steam-pressure, initial, 74 pounds; mean, $25\frac{1}{2}$ pounds; scale, 40 pounds per inch; vacuum, 26 inches; temperature of hot-well, 136° Fahr., throttle open. For diagram No. 2, the initial pressure was 75 pounds; mean pressure, $29\frac{1}{2}$ pounds. The cut-off for diagram No. 1 was 9 inches in a 72-inch stroke. The cut-off was then at $\frac{1}{8}$, but the regular cut-off is from $\frac{1}{12}$ to $\frac{1}{15}$ of the stroke.

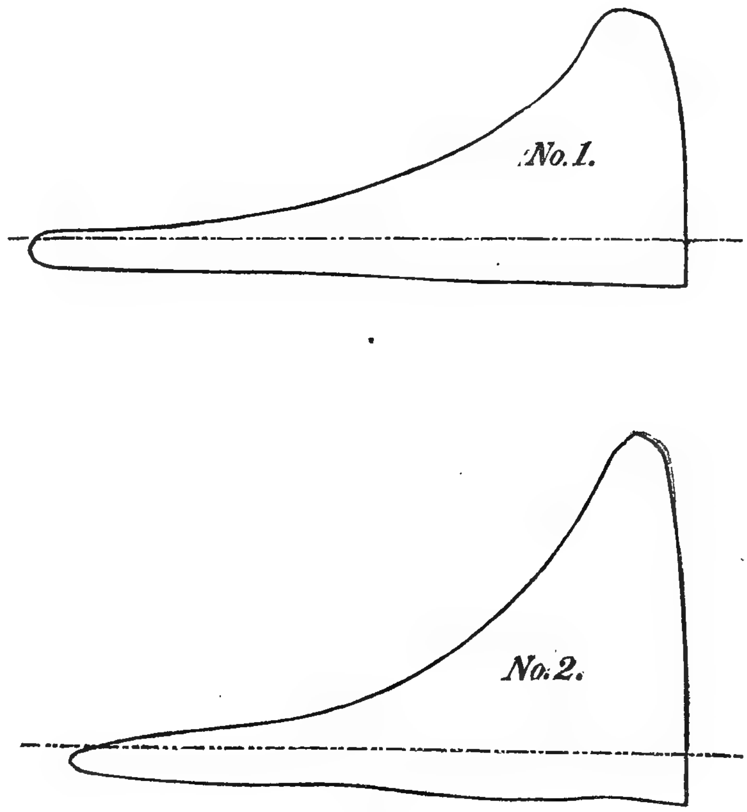


Fig. 10.

The poppet-valves are of great size, but balanced so that there is much less pressure upon their seats than with the ordinary slide-valve. The necessary lift is very slight, and the valves are held in equilibrium with dash-pots. The valve-gears of these engines work silently, and the valves do not hammer upon the seats. There are four poppet-valves operated by wipers upon rock-shafts. The admission-valves are provided with suitable gears for varying the cut-off and reversing the engines, which will be better understood from the drawings of the engines of the "Louisiana," which have similar details.

The weight of the engine is of interest, because for the power as good an economy is effected as in many compound engines of double the weight.

The following data are given of the engine of the "New Orleans," also built by Pusey & Jones: The cylinder is 48″ by 54″; air-pump, 35″ by 15″. There is one single-acting feed-pump, $5\frac{3}{4}''$ by 15″, and one 34″ rotary circulating-pump. The condensing-surface is 2,800 square feet.

The tonnage (registered) of the "New Orleans" is 1,442, the speed 11.2 knots per hour. The average number of revolutions is 64, horse-power indicated about 794, with a consumption of coal of less than 3 pounds per indicated horse-power per hour. The weight of engines (including circulating engine and attachments) is 153 net tons, and the weight of boilers is 91 tons.

Within the past few years Mr. Baird has made a new adaptation of this poppet-valve gear in the engines of the steamer "Louisiana," which were built by C. H. Delamater & Co., of New York.

The "Louisiana" is one of the largest coasting steamers, registered tonnage, 2,840.33; length, 320 feet; breadth, 39 feet; draught (loaded), about 21 feet; depth, lower hold, 14.9 feet; between decks, 11 feet; from base line to top main-deck beams, 28.6 feet. The engines remind one of two former types, the old form of side-lever engine, in that they have a pair of walking-beams, and the McNaught engine, in that they are of the compound-beam type. It is needless to say that they are quite different from either, in that they are designed for screw and not for paddle-wheel propulsion. The side-lever engine with its poppet-valves, once a popular English type, went out of vogue when side wheels were superseded by screws. The application of a smaller (high-pressure) cylinder on the crank side of the beam-engine of a river boat was made by McNaught as early as 1845, thus making a compound beam-engine, but practice failed to vindicate this type of engine for river service, and it has passed entirely out of existence.

The beam compound poppet-valve screw-propelling engines of the "Louisiana" are thus unique, as are also the boilers. The hull of the vessel was designed by Mr. Baird. Novelty involves such risks of failure that in marine engineering, as in other arts, men cling long to established precedents and hesitate to seek for further advantages, but the result in this case is one of the fastest, and, perhaps, for long runs the fastest ocean-going steamer in the world operated with a good economy of fuel.

Of the engines of the "Louisiana" two illustrations are presented. Fig. 9 exhibits their arrangement and connection upon shipboard, in elevation, looking forward and in plan. In this the valve-gear details are omitted, as well as the small bolts and panels, and such details of the frame and of the plating of the hull. For the same reason, to avoid confusion, the principal moving parts are not shown in the plan, but only in the elevation. Their position in the plan is, however, sufficiently obvious from the positions of the cylinders and the center line of the vessel. Fig. 11 exhibits the valve-gearing of the low-pressure cylinder.

From Fig. 9 we see that the beams are centered directly over the crank-shaft and the cranks are driven from the longer arms of the beams. The high-pressure cylinder being under the longer arm has a longer stroke than the low-pressure cylinder, which is upon the opposite side. The dimensions are—

	Diameter.	Stroke.
	Inches.	*Inches.*
High-pressure cylinder	30	88
Low-pressure cylinder	56	72

There are two 10″ diameter by 16″ stroke double-acting feed-pumps. These are independent of the engine.

The machinery occupies 68 feet of the length of the vessel, 26 feet being taken up by the engines and 42 feet by the boilers, the machinery being in the hold with deck-room above. Of the boilers there are 8, set athwartship and fired in the middle of the boat. The plan of Fig. 9 represents the 26 feet of length occupied by the engines and their connections. The sea connections are very clearly shown. A A are inlet-valves, and B is the outlet-valve for the centrifugal circulating-pump. The pipes are 2 feet in diameter at the largest point and 18 inches in diameter just before entering the fan. This is shown at C. It is 6 feet in diameter and has a speed of 80 revolutions per minute. D is the sea-valve for salt-water injection, and just beyond E (out of the plan) is the sea-valve for salt-water feed. F is the air-pump delivery-valve, and a 20-inch copper pipe leads to the air-pump, which is 38″ in diameter by 3′ stroke, and is operated from a crank-arm upon a shaft which connects the beam centers of the two engines. G is the filter, H the air-pump, and K the condenser, which has a surface of 7,960 square feet outside tubes. This is almost exactly half as much as the total heating-surface below the water-line of boilers, viz, 15,840 square feet, the grate-surface being 374 square feet. The heating-surface is relatively great. The coal-bunkers have a capacity of about 800 tons. The coal consumed per indicated horse-power per hour is about 2 pounds. The machinery weighs about 600 tons. The screw is of 17 feet diameter, 26 feet pitch.

The high-pressure cylinders are indicated by the letter L, low-pressure cylinders by the letter M. The letters N N N N indicate the steam-chests. The valve-gearing is actuated from the rock-shaft F in Fig. 11, to which we will now refer. This rock-shaft is in the center line of the vessel, and is driven from the main shaft. A trussed rod, L L, actuates a rock-shaft and rocker, A, whose arms B B operate, respectively, a wiper, C, for the steam- and a wiper, D, for the exhaust-valves. There are for each cylinder at each end a steam- and an exhaust-valve. The mechanism is shown for operating the lower exhaust- and the upper steam-valve. In each case there is a lifting-arm and a dash-pot, H, but the steam-valve connections (shown also in part for the lower steam-valve) are distinguished by a train of rock-shafts, rocker-arms, and links K K K (K′ for the lower valve), and other

connections for cutting off by dropping the valve upon its seat and for reversing the engine. The rock-shaft G is for disconnecting the trussed rod L by throwing out the gab at A. The lower part of the cylinder and lower poppet-valve are shown in section. For the upper valve the exterior of the chest is shown, and to avoid confusion of lines the poppet-valve is not dotted in, being the same as the lower valve.

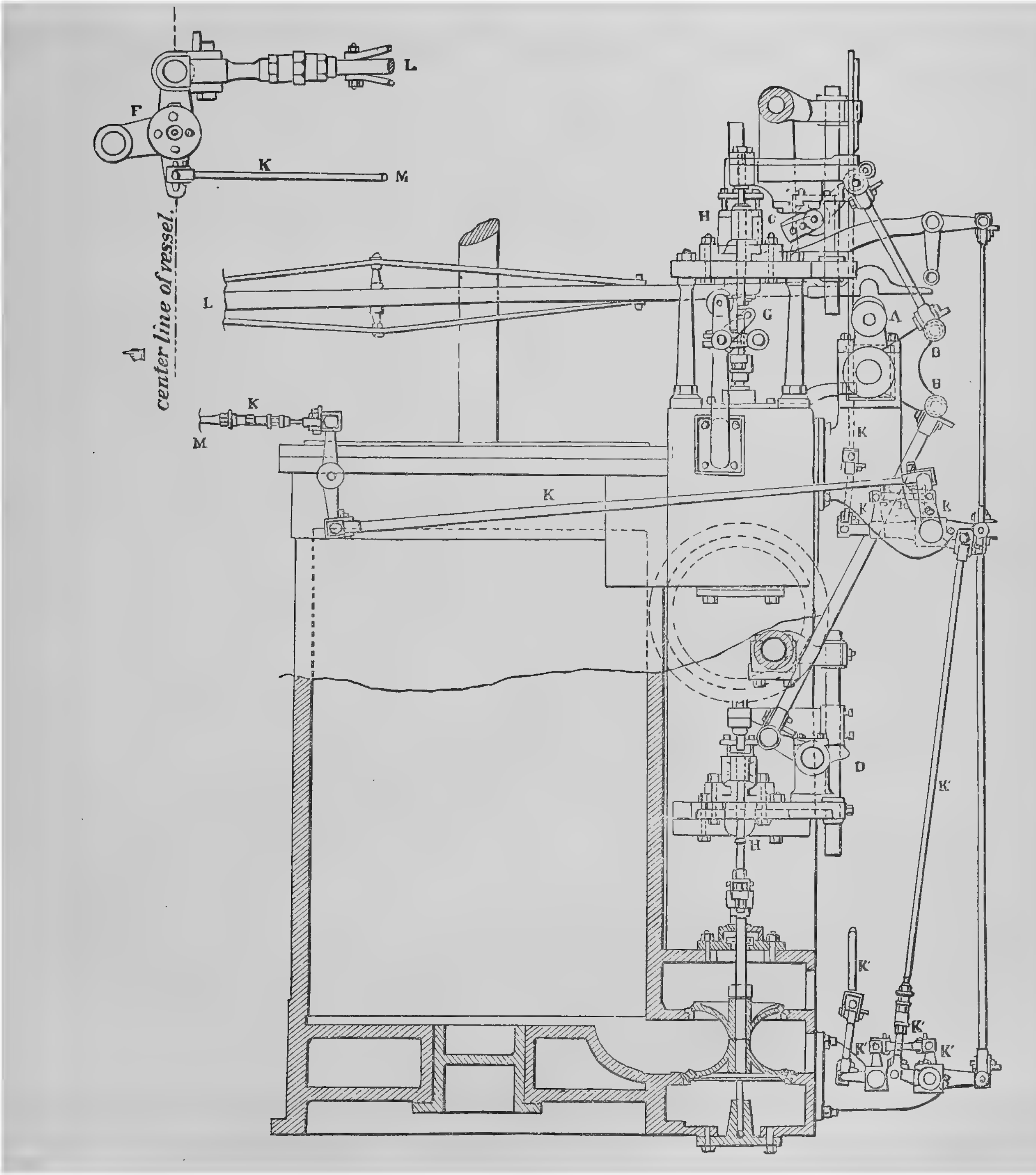


Fig. 11.

The maximum working speed of the "Louisiana" is 70 revolutions. This gives a very high piston speed for marine practice, over a thousand feet a minute for the high-pressure piston. But in a trip to New Orleans the average number of revolutions was only 58 per minute.

BEAM-ENGINES.

At the North River Iron Works (W. & A. Fletcher), New York, commencing in 1856, there have been built over 100 large beam-engines, comprising a majority of all the noted high-speed beam engines in the country. These engines were largely for fresh-water service, and are to be found not only upon the sound and river steamers of the Atlantic seaboard, but upon lake Michigan, lake George, lake Erie, and lake Champlain. Of the first 100 engines, 92 were high-pressure or non-condensing engines, 6 had jet-, and 2 had surface condensers. Nos. 101, 102, 103, and 104 have surface-condensers, and there thus appears an increasing tendency to employ condensers. Most of these engines were built for river and harbor use, and for comparatively short routes, and the practice has been in many cases to provide them with fresh-water tanks.

Now that many of the troubles first experienced with surface-condensers, not the least of which was the deterioration of the iron in the boilers (where water from surface-condensers has been used), have been overcome, only the additional first cost prevents many from having the surface-condenser.

W. & A. Fletcher's one hundredth engine was built for a new steamer of the New York, Catskill, and Athens Steamboat Company. The steamer is 265 feet long, 38 feet beam, and 10 feet depth of hold. The engine has a 63″ cylinder and a 12′ stroke. The boilers have 9′ diameter shells, and are 34′ long, the steam-chimneys being 48″ inside and 88″ outside shell diameter, and 13′ high.

Of these hundred engines, ninety-nine had the Stevens and one the Sickels cut-off. (The former is shown in the illustrations of the engines of the "Pilgrim," built by John Roach & Son, and the latter in the illustration of the engines of the "Louisiana," built by C. H. Delamater & Co.) While the method of operating the poppet-valves by means of rock shafts, wipers, and lifters is similar in both forms of cut-off, the Sickels is distinguished by the release of the lifters and valves from the lifting toes or cams at a point of the stroke, when the valves drop lightly upon their seats, being restrained from striking them heavily by connection with a piston working in a dash-pot of oil or water.

As an example of the beam-engines of river steamers, we may take that of the "Mary Powell." This has the Stevens cut-off, with two eccentrics and two rock-shafts, one for steam- and one for exhaust-valves, and four lifter-rods, bearing eight arms or lifters. The cylinder is 6′ in diameter by 12′ in stroke. The diameter of the piston-rod is 8″; of main shaft, 1′ 3″; journals, 1′ 3$\frac{5}{8}$″ in diameter and 1′ 5″ long. The crank-pin is 8$\frac{3}{4}$″ in diameter and 10$\frac{3}{4}$″ long. The air-pump is 40″ diameter by 62″ stroke. The steam- and exhaust-valve openings in the steam-chest are 1′ 2$\frac{3}{4}$″ in diameter. Displacement of piston per revolution, 676 cubic feet; clearance at both ends of cylinder, 25 cubic feet. The following data are given of a trial in 1877:

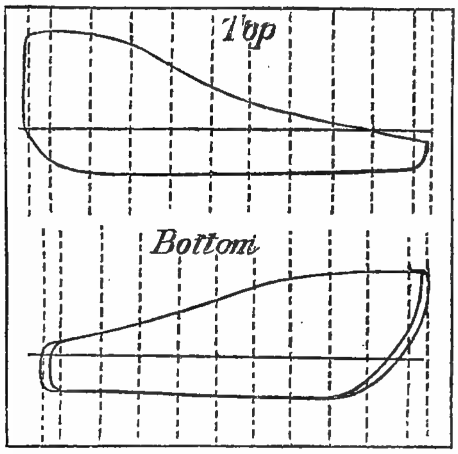


FIG. 12.

Per hour—speed of vessel, 19.3 miles; revolutions, 1,306 (21$\frac{5}{8}$ per minute); coal, 5,970 pounds, combustible (coal less ash), 4,870 pounds; coal per square foot of grate, 39.3 pounds; per square foot of heating-surface, 2.25 pounds. The temperature of atmosphere was 70°; of hot-well 120°; of chimney gases, hot enough to melt zinc (over 782°). Indicator diagrams are shown in Fig. 12, with the following particulars: Steam-pressure above atmosphere, 28 pounds; vacuum, 25 inches (mercury); initial pressure, 40 pounds; pressure at cut-off, 31.2 pounds; at end of stroke, 16.4 pounds; mean back pressure, 5.6 pounds; at end of cushioning, 40 pounds; mean total pressure, 29.94 pounds; mean indicated pressure, 24.34 pounds; net indicated pressure, allowing for friction, 22.84 pounds. Cut-off, 0.47, and cushioning at 0.8 in fractions of the stroke. Horse-power, total, 1,899; indicated, 1,540; net, 1,446. Pounds steam per hour for diagrams, 42,000. Economy of boiler, 7 pounds water per pound coal from 120°, 7.8 pounds from 212°. Economy of engine, pounds steam per hour per total horse-power, 22.1; per net indicated horse-power, 28.9. Coal per horse-power, total, 3.14 pounds; indicated, 3.87; net indicated, 4.13 pounds.

INCLINED MARINE ENGINES.

The "inclined" marine engine was designed by Charles W. Copeland, mechanical engineer, in 1839, and a patent for it was issued to him June 11, 1841. Before the successful introduction of the screw-propeller it became a favorite engine for side-wheel sea-going steamers. It was and still is preferred by many ferry companies for their ferry-boats, for which purpose it is peculiarly adapted. The following is a general description of its arrangement and a copy of the claims of the patent:

The cylinders in this arrangement of the engine are inclined at an angle dependent upon the depth of the hold and the length of stroke, and they are fastened to inclined beams extending from the paddle-wheel shaft to the keelsons, said beams being connected with the keelsons along their whole length by other beams and by bolts, the whole constituting truss-frames, which may be of wood or iron, which sustain and divide the weight and jar of the engines.

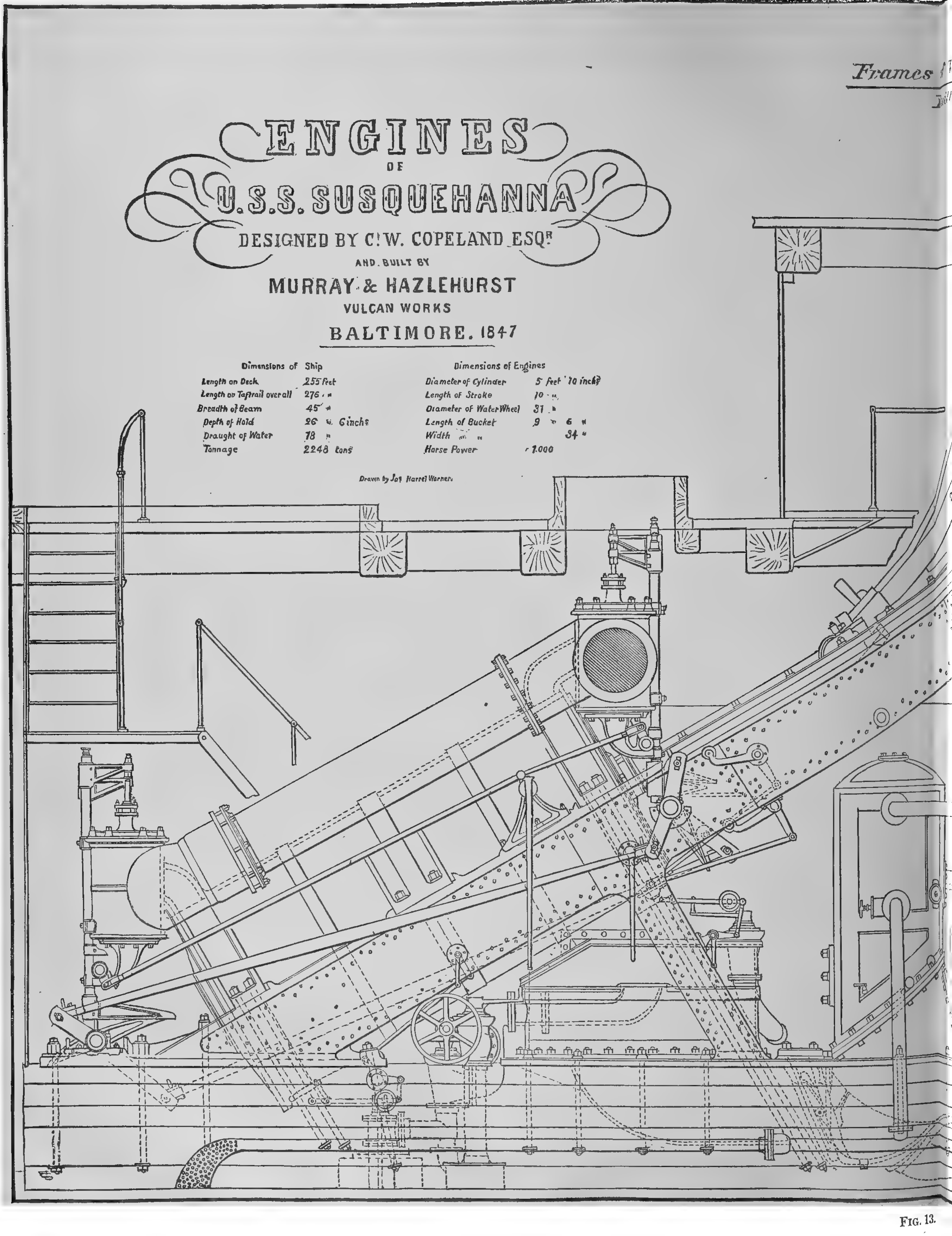
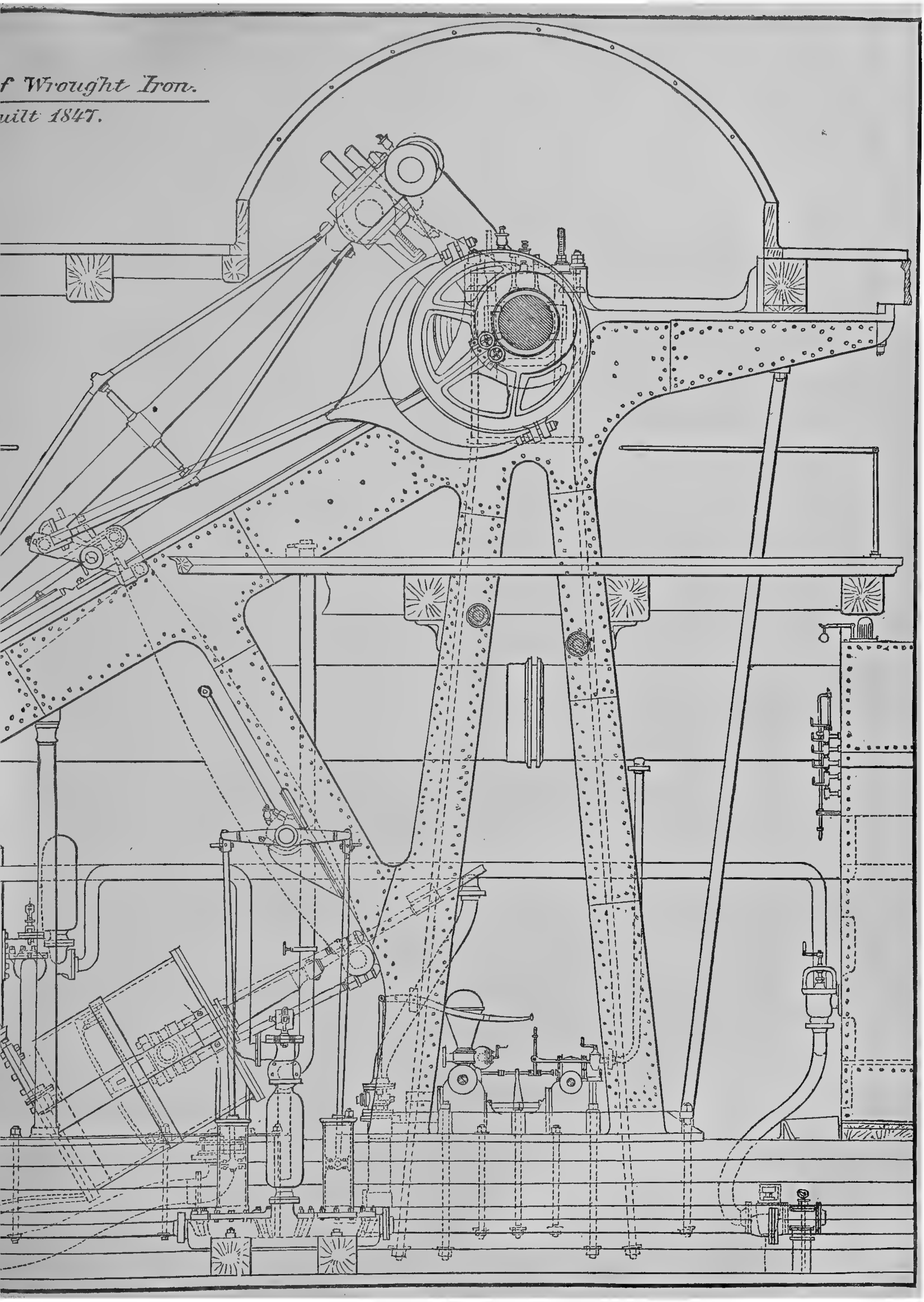

ENGINES
OF
U.S.S. SUSQUEHANNA
DESIGNED BY C! W. COPELAND ESQ^R
AND. BUILT BY
MURRAY & HAZLEHURST
VULCAN WORKS
BALTIMORE. 1847
Dimensions of Ship
Length on Deck 255 Feet
Length on Taftrail overall 276 "
Breadth of Beam 45 "
Depth of Hold 26 " 6 inches
Draught of Water 18 "
Tonnage 2248 tons
Dimensions of Engines
Diameter of Cylinder 5 feet 10 inches
Length of Stroke 10 "
Diameter of Water Wheel 31 "
Length of Bucket 9 " 6 "
Width " " 34 "
Horse Power 1.000
Drawn by Jas Harrel Warner.
Frames

FIG. 13.


f Wrought Iron.
uilt 1847.

The condensers are directly under the upper end of the cylinders, and the channel-plates run between the keelsons. The lower ends of air-pumps, which are inclined as well as the cylinders, are secured to the ends of the said channel-plates, and the hot-wells to their upper parts. The delivery-valves are placed on the upper side of the channel-plates. The pistons of the air-pumps in this arrangement are solid, and the whole apparatus is rendered compact, and the whole placed within the observation and reach of the engineer.

The side pipes are placed above the cylinders, the steam-chests at each end thereof, and the valve-stems running either down in front of the head of the cylinder to the rock-shafts or extended above with rock-shafts above the chest. The feet are attached directly to the stems, instead of to lifting-rods, and are acted upon by the toes of the rock-shaft, the two rock-shafts being connected together by a rod.

Claim: What I claim as new and constituting my invention is—First. The placing of the cylinder in an oblique direction, with the lower end near to the bottom of the vessel, and allowing it to stand at such an angle as is required for the connecting of its piston-rod with the crank on the shaft of the paddle-wheels, in combination with the condenser, channel-plate, and air-pump, arranged and located as described. I do not claim the mere placing of the cylinder of a steam-engine obliquely, as this has been done for other purposes, but as I produce a new and useful effect by so placing the steam-cylinder and its appendages in the combination above claimed, on board of vessels for navigating the ocean, I limit my claim to the so placing them under the said combination as to obtain the object fully made known.

Secondly. I claim the manner of arranging and working the steam- and exhaust-valves as set forth, the same being effected by a direct action, that is to say, without the employment of the lifting-rods and lifters usually required for that purpose.

Thirdly. I claim the manner of combining and arranging the condensing apparatus, the air-pump being placed at the same angle, or nearly so, with the cylinder, and attached by its lower end to the channel-plate, the delivery-valve being also placed on the upper part of the said plate; the combination intended to be claimed under the last head consisting in the arranging of the several parts enumerated, that is to say, the air-pump, the channel-plate, the delivery-valve, substantially in the way described.

From this description it will be seen that all parts of the engine are below the paddle-wheel shaft, and that all parts are immediately under the eye of the engineer, and perfectly accessible for adjustment and lubrication, even when the engine is in operation. It is also more simple and direct in its operation, and the center of gravity is much lower than in a beam-engine. Its weight and cost and expense of repairs are also less. For a sea-going vessel it has the advantage that any "working" of the vessel affects the alignment less than in either the beam or the side-lever engine. It has the further advantage that any ordinary length of stroke may be adapted to the vessel without respect to the depth of the vessel's hold, and without materially affecting the height of the center of gravity.

For ferry-boats the engine has the further advantage that it occupies less deck-room, which is valuable for the accommodation of carriages and teams, the whole of the engine being placed in the hold, thus occupying room which otherwise has no value for a ferry-boat.

Both the Stevens and the Sickels cut-offs have been used on this engine, the former generally on sea-going vessels and the latter from its convenience on ferry-boats. The difference in these two styles of cut-off is that in the former, as usually constructed, when the engine is in operation, the point of cut-off can only be changed so as to *increase* the admission by taking a part of the motion from the exhaust-valve movement, whereas with the latter it can be either increased or decreased at will. In the former the valve follows the valve mechanism in returning to its seat and cutting off steam, but in the latter the valve is detached from the valve mechanism and returns or falls to its seat by the action of gravity aided by the pressure of the atmosphere or of springs.

The inclined engine has been used in the following steamers of the United States navy: The "Susquehanna," "Saranac," "Michigan," "Scorpion," "Harriet Lane," "Missouri," and several others, and on a number of merchant steamers; also on ferry-boats at Boston, New York, Albany, Newburgh, Philadelphia, and Detroit. It has also been used for ferry-boats in South America and in Cuba. The inclined engines of the "Susquehanna" were at one time run for 24 consecutive days without stopping, a run probably never equaled in any other steam vessel.

In Fig. 13 we have an illustration of the inclined engine with Stevens' cut-off as described. The ferry-boat engines differ from this in having the Sickels cut-off. The frame of the engine shown is of wrought iron; cast iron being the material ordinarily used.

AUXILIARY ENGINES.

The statistical tables of engines and boilers have reference only to principal engines used in propulsion, but the report would be incomplete without allusion to the great numbers of auxiliary engines which are coming more and more into use upon all large American steamers. These engines are used for pumping, freight-handling, steering, winding-in chains and rope, and for other purposes. The pumping-engines are in most cases properly auxiliary to the main engines, and some have been described in that connection, but the freight handling engines, and even more, the steam capstans and windlasses, are to be ranked among those new labor-saving developments which are gaining a foothold in modern practice. A few words will point the value of labor-saving contrivances on shipboard. In handling freight the value of promptness in loading and unloading is illustrated by the Reading Railroad Company, whose colliers save time by loading and discharging cargoes at night, aided by electric lights. This company pays premiums for prompt unloading, and the report of Mr. John L. Howard, its superintendent, states that during 1879 $59,483 was paid in premiums for prompt unloading, and in 1878 $61,481 was paid in premiums. The smaller sum was the value of 878 days saved above the stipulated allowance of time for a fleet of 13 steamers.

The "Chalmette," beside 9 other auxiliary engines, has 5 freight-hoisting engines, built by Williamson Brothers, Philadelphia, which are arranged so as to work the after capstan and handle the sails, and to perform other kinds of work; and a steam-windlass and forward capstan by the American Ship Windlass Company, Providence. It becomes simply a matter of letting on steam to a single cylinder, and any desired amount of power may be obtained for a purchase for any kind of work. For steering, reversing, and handling a steamer, steam attachments not only give greater facility but often greater safety. Steam machinery works readily in severe and inclement weather. Captain Lefevre, of the (Savannah) Ocean Steamship Company, says of the steam-capstan: "It takes up but little room, and can be worked effectually where men could not exert their force with bars or cranks on decks covered with ice and snow." It is said by experienced navigators that a large steamer "rigged with a steam-windlass forward and a steam-capstan aft can be handled as easily as a row-boat". Steam-capstans or capstans and windlasses are used on the "City of Pekin," "Decatur H. Miller," "Louisiana," "Bristol," "Providence," "City of Augusta," "Manhattan," and many other steamers mentioned in this report. They are largely employed upon the lake propellers. The steam yachts "Corsair," "Stranger," and "Polynia" have steam windlasses. The Mississippi river stern-wheel boat "Joseph B. Williams" has several steam-capstans.

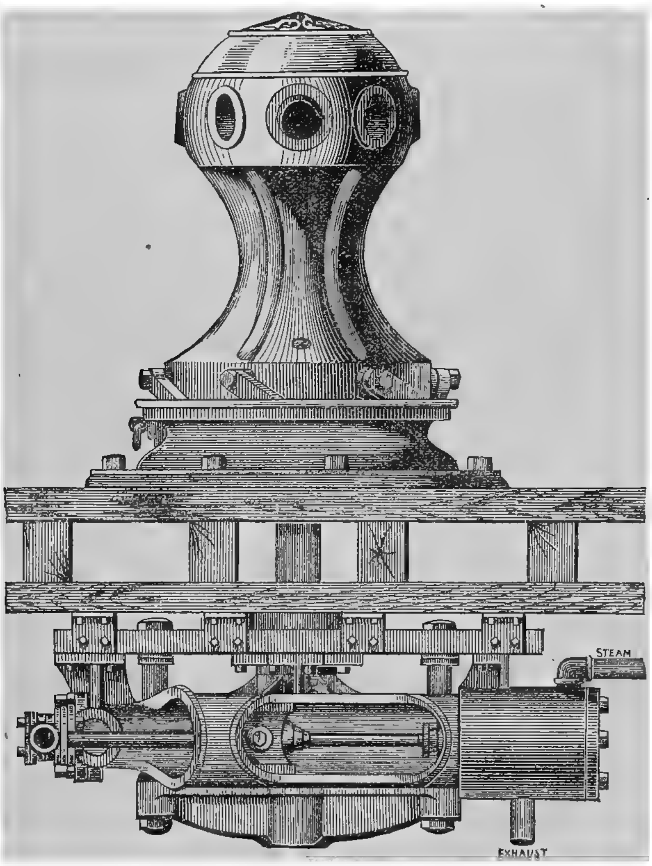


FIG. 14.

In Fig. 14 is illustrated the form of steam-capstan used by several large Oregon steamers. It is also used upon tug-boats at Pittsburgh and at New Orleans, and very generally upon the Atlantic steamers. Steam is also applied in operating the pump-brake windlass, and the Providence steam capstan-windlass is a popular style. In this the piston-rods of two horizontal cylinders at right angles, bolted under the capstan-deck, operate a single crank upon a vertical shaft. A screw on this shaft gears into a worm-wheel on the windlass-shaft on the lower deck, and the standing-shaft of the capstan is driven by a bevel-wheel gearing into one on the windlass-shaft. A later style of steam-windlass has the advantage over the former that all the machinery is attached to one deck, and thus is less liable to get out of line. The steam-valve is operated by an eccentric, and a screw on the crank shaft drives a worm on the windlass-shaft.

The American Ship Windlass Company, Providence, Rhode Island, began to introduce steam-windlasses eighteen years ago. To-day they are almost essential to large steamers. American steamers are better equipped in this respect than English, or any other foreign vessels, and American steam-windlasses have been applied on some of the Cunard steamers, the French yacht "Bretagne," and other foreign vessels. One instance will suffice to illustrate their advantage in handling a steamer. The steamship "City of Tokio" carries 7,000-pound anchors, using a $2\frac{5}{16}$-inch chain. It would take forty men an hour to get in sixty fathoms of chain with the best hand-windlass made, but with the steam-windlass used (a Providence windlass), one man and a boy will take in the same quantity of chain in six minutes. The labor saved for equal times is more than two hundred fold, but this is not the most important consideration. In backing steamers into the wharf, in maneuvering in harbors or in narrow channels, in cases where a steamer gets aground, and in many other situations, promptness of action may make a little time almost invaluable.

ENGINES OF PHILADELPHIA STEAMERS.

In Class I all of the engines are condensing, and of 21 steamers, 18 are screw-propellers or screw-steamships. The "Canton," 1,178.55 tons, plying inland from Philadelphia, has two 3′ by 9′ beam-engines, and the "Republic," 1,285.02 tons, also plying upon inland routes, has one 66″ by 12′ beam-engine.

The engines of the steamers of the American line to Liverpool are elsewhere considered. Apart from these, the Reading colliers constitute the most notable group of large steamers in the Philadelphia district. These are typical American freight-boats, and have done an immense service. The following list comprises the fleet of colliers,

with the tonnages, dimensions of engines, and boiler-pressure allowed. The dates when each vessel commenced to run are also given, from which it will be seen that the shipping has been built up almost entirely within the past decade:

Name of collier.	When first run.	Registered tonnage.	ENGINES. No.	ENGINES. Dimensions.	Boiler-pressure allowed.
Rattlesnake	June, 1869	417.44	1	34″ x 28″	27
Centipede	Sept., 1869	436.88	1	34″ x 28″	33
Achilles	Mar., 1870	763.51	1	40″ x 30″	33
Hercules	May, 1870	764.33	1	40″ x 30″	25
Leopard	July, 1870	....	......	....	....
Panther	Aug., 1870	699 10	1	40″ x 30″	33
Reading	Apr., 1874	1,283 00	1	42″ x 42″	33
Harrisburg	June, 1874	1,283 00	1	42″ x 42″	33
Lancaster	July, 1874	1,283.00	1	42″ x 42″	33
Perkiomen (a)	July, 1874	1,035.35	1	27″ & 45″ x 30″	60
Berks (a)	Aug, 1874	553.09	1	20½″ & 34″ x 30″	60
Williamsport	Sept., 1874	1,283.00	1	42′ x 42″	33
Allentown	Oct, 1874	1,283.00	1	42″ x 42″	33
Pottsville	Dec., 1874	1,283.00	1	42″ x 42″	33

a Compound.

In Class II there are 33 engines, 15 beam and 18 direct-acting. All of the screw-propeller engines are upon coasting vessels, and nearly all of the beam-engines are in the river service. All are condensing.

The "Excelsior," 774.43 tons, an inland steamer, has two beam-engines, each 40″ by 10′; boiler-pressure allowed, 55 pounds. The coasting steamer "Santee," 658.64 tons, has one 40″ by 3′ engine; boiler-pressure allowed, 23 pounds. The ferry-boat "General J. S. Schultz," 536.51 tons, plying between Philadelphia and Camden, has one 36″ by 10′ beam-engine; boiler-pressure allowed, 45 pounds. The steamer "Admiral," 508.68 tons, coasting upon the Atlantic and the gulf of Mexico, has one 48″ by 9′ beam-engine; pressure allowed in boiler, 30 pounds.

In Class III 34 out of 95 engines are non-condensing, and 33 out of 95 are engines of boats having paddle-wheels. The "City Ice-Boat No. 2," of 458.02 tons, is a side-wheel boat, driven by two 48″ by 8′ non-condensing engines. The boiler-pressure allowed is 60 pounds. The engines are of great power, which is required for cutting and crushing through ice to keep navigation open in the Delaware river.

The ferry-boat "Barclay," 166.84 tons, plying between Tuckerton and Beach Haven, has side-wheels driven by two 17″ by 36″ non-condensing engines. The boiler-pressure allowed is 60 pounds.

In this class the great majority of the engines are simple short-stroke engines driving-screw propellers. In the next class all but two or three are of this type, and 20 out of 35 are non-condensing. In Class V nearly every engine is of the short stroke type, and only one is condensing. In Class VI all are non-condensing, and two or three very small paddle-wheel boats furnish the only exceptions to the usual short-stroke type of engine.

The canal-boat "Triplet," 338.79 tons, has one 22″ by 36″ engine; boiler-pressure allowed, 75 pounds.

ENGINES OF BALTIMORE STEAMERS.

In Class I there are 8 engines, all condensing, 2 beam-engines on passenger-boats plying on Chesapeake bay, and 6 vertical screw-propeller engines on coasting steamers. The "Johns Hopkins," 1,470.97 tons, has one 60″ by 44″ engine; boiler-pressure allowed, 33 pounds. The "Louise," 1,023.20 tons, has one 50″ by 11′ engine; boiler-pressure allowed, 36 pounds.

In Class II there are 30 engines, only 2 non-condensing and only 8 screw-propeller engines, the rest being beam-engines on steamers plying on Chesapeake bay. The propeller "Shirley," 576.30 tons, plying between Baltimore and Richmond, has one 34″ by 34″ engine; boiler-pressure allowed, 30 pounds. The "Carolina," 984.18 tons, plying between Richmond and Norfolk, has one 60″ by 11′ engine; boiler-pressure allowed, 38 pounds. The "Carolina" is a swift boat, about the size of the "Mary Powell," of the Hudson river, but not as swift. The following comparison is made between the two boats:

	Carolina.	Mary Powell.
Tonnage	984.18	983.57
Length .... feet..	257	288.7
Breadth .... feet..	34.7	34.4
Depth .... feet..	7.9	9.0
Engine	60″×11′	72″×12′
Speed .... miles per hour..	15¾	19½*a*

a At high speeds the engine of the "Mary Powell" exerts 1,500 horse-power. The speed given is for a 90-mile run, and has been exceeded in short runs.

The screw-steamer "William Kennedy," 974.57 tons, has one 44″ by 6′ engine; boiler-pressure allowed, 35 pounds.

In Class III, of 56 engines there are 23 long-stroke engines, generally peculiar to ferry and inland passenger-boats. The "William Allison," a large towing-boat with a beam-engine, is an exception to this rule. The majority of the engines are condensing, only 22 out of 56 being non-condensing. But in Class IV out of 21 engines only 4 are condensing, the boats being screw-propellers excepting one, the steamer "Arlington." In Class V 2 out of 46 are condensing-engines, while in Class VI all are non-condensing and short-stroke of the usual type for small tugs and yachts.

The Pennsylvania canal-boat "No. 222", 73.40 tons, has one 14″ by 14″ engine; boiler-pressure allowed, 72 pounds. The passenger-boat "Arlington," 51.33 tons, has one 16″ by 4′ engine; boiler-pressure allowed, 80 pounds. The passenger-boat "Convoy," 78.98 tons, has one 32″ by 30″ condensing-engine; boiler-pressure allowed, 40 pounds. The "A. S. Kapella," 21.55 tons, has one 14″ by 14″ engine; boiler-pressure allowed, 80 pounds.

ENGINES OF NORFOLK, CHARLESTON, AND SAVANNAH STEAMERS.

The "City of Macon," 2,092.80 tons, of the New York and Savannah line, has one 38″ and 68″ by 54″ compound engine, with a boiler-pressure allowed of 80 pounds. The ferry-boat "Manhausett," 512.43 tons, plying between Norfolk and Portsmouth, has one 38⅝″ by 8′ engine, with a boiler-pressure allowed of 30 pounds. The "City Point," 678.06 tons, plying between Charleston and Palatka, has one 45″ by 11′ engine; boiler-pressure allowed, 40 pounds. The steamer "Calvert," 637.37 tons, plying between Charleston and Baltimore, has two 40″ by 36″ engines; boiler pressure allowed, only 18 pounds.

Of the smaller steamers inspected at Norfolk a large proportion run to points on the North Carolina sounds, and these, with a smaller number running to Richmond and points on the James river, constitute nearly all of the steamers. Most of the passenger-boats have long-stroke beam-engines, while the freight-boats and tugs have short-stroke propeller-engines. The freight-boat "Benjamin Meinder," 127.70 tons, plying from Plymouth, North Carolina, as far north as Philadelphia, has one 18″ by 18″ non-condensing engine; boiler-pressure allowed, 50 pounds. The tug-boat "Tredegar," 34.12 tons, plying between Norfolk and Plymouth, has one non-condensing engine 13″ by 13″; boiler-pressure allowed, 60 pounds. The tug-boat "Vulcan," 50.90 tons, plying upon James river, has one non condensing engine 20″ by 20″; boiler-pressure allowed, 40 pounds. In Class III, 16 out of 29; in Class IV, 2 out of 31, and in Class V, 1 out of 28 engines are condensing. There are two boats with oscillating engines. The tug-boat "Annie Wood," 15.26 tons, plying between Franklin and Edenton, has one 6″ by 9″ oscillating engine, and the "Chipoax," 43.92 tons, plying between Petersburg, Norfolk, and Richmond, has two oscillating engines, each 8″ by 8″.

Of the smaller steamers inspected at Charleston, in Class III, 7 out of 22; in Class IV, 5 out of 13; in Class V, 2 out of 18, and in Class VI, 1 out of 17 engines are non condensing. In Class III the engines are mostly long-stroke, driving paddle-wheels, but in Class VI there are only two such engines.

The freight-boat "Mingo," 26.40 tons, plying upon the Santee and Pedee rivers, is a paddle-wheel boat with one 8″ by 30″ engine; boiler-pressure allowed, 80 pounds. The "Flora," 86.48 tons, a side-wheel passenger-boat, of Jacksonville, Florida, has two inclined engines, each 10″ by 11″; boiler-pressure allowed, 67 pounds.

Of the small steamers inspected at Savannah, in Class III, 7 out of 29; in Class IV, 7 out of 30; in Class V, 5 out of 16, and in Class VI, 4 out of 30 engines are condensing. The Savannah district is characterized by a great number of paired engines, for of the classes of steamers below the second we find in the Norfolk district about 18 per cent., in the Charleston district about 40 per cent., and in the Savannah district about 61 per cent. of the engines used in pairs. Excepting in the smallest boats, such paired engines are usually of long stroke for driving paddle-wheels. In Class III, of Savannah, 22 out of 29 engines are used in pairs, and 28 out of 29 are used in driving paddle-wheels. The "Gazette," a screw-boat of 117.98 tons, in passenger service on the Saint John's river, has one 14″ by 16″ engine; boiler-pressure allowed, 70 pounds. The "Fox," a paddle-wheel tug-boat of 117.98 tons, plying between Salt Lake and Jacksonville, Florida, has one 8″ by 18″ engine; boiler-pressure allowed, 75 pounds.

ENGINES AND BOILERS OF THE "CITY OF AUGUSTA."

The engines of this fine steamer were built at the Delaware Iron Shipbuilding and Engine Works, Chester, Pennsylvania. There is one principal compound engine 42½″ and 82″ by 54″ (stroke) cylinders. The surface-condenser has 4,200 square feet of surface, and, as is often the case on ocean steamers, may be arranged to work as a jet-condenser if desired. Separate engines work the air-, feed-, and bilge-pumps, and the circulating-pumps. The air-pump is independent of the circulating-pump, and the bilge-pumps connected with the air-pump may be disconnected if desired. There is also a starting- or reversing-engine supplied with steam from a separate donkey-boiler. The shaft is 14½″ in diameter, journals 24″ long with 2½″ deep by 2″ thick collars. The propeller is of the Hirsch pattern, 16′ in diameter, 24′ pitch, with a 15½″ shaft. The boilers are six in number, return-tubular, 12′ 6″ in diameter and 11′ 5″ long. The tubes are 8′ long and 3¼″ diameter. Each boiler has three furnaces, 33″ in diameter, with grate-bars 6′ 6″ long. Small steam-engines are employed for hoisting, steering, and other purposes.

ENGINES OF GULF STEAMERS.

In the Apalachicola district long-stroke engines in pairs are the most common type for all but the smallest vessels. The river boat "Rebecca Everingham," 592.20 tons, has two $10\frac{1}{4}''$ by $4'$ $6''$ engines, which at the boiler-pressure allowed, 183 pounds, will develop a high power in proportion to the size of cylinders. The "Laurel," 320 tons, has two inclined direct-acting engines $21''$ by $27''$ each; boiler-pressure allowed, 30 pounds. The paddle-wheel boat "Alpha," 93.73 tons, has two slide-valve engines each $6\frac{1}{2}''$ by $24''$; boiler-pressure allowed, 80 pounds. In this district four-fifths of the engines are non-condensing, and two-thirds of them are used in pairs.

At Mobile no steamers of over 500 tons are inspected. The larger steamers are of the regular river type, with stern-wheels driven by pairs of horizontal (or slightly inclined) engines of long stroke. This class of engines will be more fully considered under the head of "Steamers of the Mississippi Valley". The smaller steamers are screw-propellers with short-stroke engines. The engines of both classes are almost uniformly non-condensing, there being only 7 condensing-engines in a total of 104 engines in the district, and these with one exception being upon the propellers. The tug-boat "Juno," 80.31 tons, has a compound engine $16''$ and $28''$ by $20''$. In Class III, 40 out of 46; in Class IV, 12 out of 24; in Class V, 8 out of 14, and in Class VI, 8 out of 20 engines are used in pairs.

In the Galveston district there are four compound engines, the tug-boat "Estelle," 84.78 tons, having two $12''$ and $21''$ by $24''$ engines, and the "Louise," 105.01 tons, having two similar engines. This district differs from that of Mobile in the considerable and increasing employment of condensing-engines. Thirteen out of 41 engines were condensing in 1880, and in 1881 17 out of 40 engines were condensing. In the interval of a year specified some steamers had been transferred, 8 had gone out of service, and 11 new steamers had come into service, 5 of them with condensing-engines.

In Class I, New Orleans, 15 out of 39 engines are condensing, and 26 out of 39 are paired. In Class II, 7 out of 23 are condensing and 16 are used in pairs, that is to say, all the side-wheel and propeller engines are condensing, while all the stern-wheel engines are paired. The "Garden City," 982.10 tons, a stern-wheel boat, has two $22\frac{1}{2}''$ by $8'$ engines; boiler-pressure allowed, 156 pounds. The "Morgan," 994.31 tons, a side-wheel boat, has one $50''$ by $11'$ engine; boiler-pressure allowed, 30 pounds. The cylinder capacity of the "Garden City" is 42.92 cubic feet, of the "Morgan" 150.33 cubic feet, but the former uses the greater power.

In Class III, New Orleans, 19 out of 163 engines are condensing and 138 are paired. Also one steamer, the ferry-boat "Porter," a propeller of 280.35 tons, has four $16''$ by $16''$ engines; the boiler-pressure allowed being 45 pounds. In Class IV 4 engines out of 71 are condensing, 56 are paired, and one steamer has four engines. It will be seen that these classes are almost entirely composed of stern-wheel boats.

In Class V 18 out of 39 engines are paired and 38 are non-condensing. In Class VI 18 out of 59 are paired, beside which there is one set of four engines (upon the tug "Ruby"), and all the engines are non-condensing.

Only engines used in propulsion are specified above. We speak, for example, of the "Chalmette" as having one compound engine, but counting small engines for all purposes it has no less than 15 engines on board.

The steamship "Algiers," of the Lone Star line, plying between New Orleans and New York, has a long-stroke poppet-valve engine with Sickels' cut-off. The "Algiers" is a vessel of 2,287.34 tons; length, 281 feet; breadth, 38.7 feet; depth, 20.2 feet. It has one $50''$ bore by $5'$ stroke simple-condensing engine. Cutting off at $6''$ (one-tenth) the economy is stated to equal that of a compound engine. The "Algiers" has a $4''$ by $20''$ feed-pump and two $11'$ $4''$ diameter $17'$ long return-tubular boilers, shells iron $\frac{9}{16}$ thick, carrying 60 pounds pressure.

CONDENSERS.

Surface-condensers have played a very important part in increasing the economy of marine service. It may almost be said that they have rendered long ocean voyages practicable, for the chief obstacle to higher speeds lies in the necessity for carrying a great weight of coal to obtain the requisite power. But without surface-condensers twice as much coal would have to be carried, and indeed the best results obtained with marine engines to-day show a consumption of about one-fourth as much coal per horse-power as the best results of forty years ago. The chief factor of this improvement has been the employment of surface-condensers. We might say, roundly, that, going back one, two, three, and four decades, the best economy in marine steam-power has been the consumption of 3, 4, 5, and 6 pounds coal per horse-power per hour. Now it is less than 2, and in some cases is claimed to be less than $1\frac{1}{2}$ pounds. Estimating 10,000,000 tons of coal to be annually used in the work of marine propulsion, it would cost $30,000,000 or $40,000,000 a year, and occupy over 6,000,000 cubic feet of cargo-space the year round, the use of which would be worth nearly as much as the cost of the coal that fills it. Granted that the saving is equal to the use, and we have an impressive showing of the world's annual indebtedness to the surface-condenser and the improved usage of steam machinery which followed its introduction. Of American steamers surface-condensers are used upon only a small percentage by number, but upon a large percentage by tonnage. The common form of surface-condenser for large engines consists of a great number of small parallel tubes so arranged within a casing that the exhaust-steam passing through the tubes is condensed by cold water flowing through the spaces between them.

The efficiency of surface in condensing and the proportionment of areas for surface-condensers are dependent upon conditions which may be exactly determined in any given case, but which are subject to much variation.

Condensing, like heating-surfaces should therefore be made ample enough to cover all probable conditions. A condensing-engine, under various grades of expansion, may be expected to require between 16 and 30 pounds of water per horse-power per hour. The vacuum in a condenser being 13 pounds per square inch, a square foot of condensing-surface suffices to condense 3 or 4 pounds of steam per hour, according to experiments upon a marine engine cited by Rankine. According to Peclet, 21½ pounds of steam are condensed per square foot per hour, the tubes being of copper and the initial temperature of the cooling water being between 68° and 77° Fahr. As a matter of practice, we find that surface-condensers are made to condense 8 to 12 pounds of steam per square foot of area. A number of examples of good practice with large marine engines give the number of square feet of condensing-surface per actual indicated horse-power at 3.73, 2.74, 2.66, 2.66 (another engine), 2.07, 2.00, 2.00, 1.83, 1.81, and 1.68 square feet. The consumption of water per indicated horse-power varied in these cases, but supposing the steam dry and 20 pounds of steam consumed per indicated horse-power, the weight of steam condensed per square foot of surface would range between 5⅓ and 12 pounds. With greater economy of steam there would be less power and a greater relative area of condensing-surface, say 1 square foot for 4 pounds per hour. Under favorable conditions, over 2 square feet of condensing-surface per indicated horse-power is redundant surface, and involves little or no economical advantage for the best engines, but for engines wasteful of steam much more surface would be necessary.

Making the condensing-surface five-eighths as great as the heating-surface is stated by Mr. Henry Levrat to be an ordinary rule of practice. Examples have been noted in which the condensing-surface varies from seven-eighths to little more than half the heating-surface, and two thirds is a very common and effective ratio. It is obvious that the temperature of the water used and the efficiency of the circulating-pumps affect the vacuum obtained.

The surface-condenser was first successfully introduced in English marine service between forty and fifty years ago by Mr. Samuel Hall. A practical difficulty in its introduction was due to the leakage of the tubes, which are held at the ends in tube sheets, in which it is necessary that they should be packed steam and water tight. The variations in temperature, and the consequent expansion and contraction of the tubes, commonly called "creeping", have always caused more or less trouble. Hall used packing held in place with a screw-ring, without a creep-flange. For making the surface-condenser a practical success in American marine service the chief credit is due to Horatio Allen, of the Novelty Iron Works, New York. He introduced the wood packing, which was originally used as shown in Fig. 15. A wood ring or ferrule was driven over the tube, passing between it and the tube-sheet. Driven in dry, it became swollen by the moisture and expanded, making a tight joint and spreading out at the ends like the flanges of a spool. The tubes were nicked out to prevent "creeping". Wood packing was first applied in the steamers of the Pacific Mail Steamship Company. Another approved method of packing is by brass rings with creep-flanges. Brass plates are sometimes used instead of cast iron, being more expensive, but less subject to corrosion from distilled water. Double sheets or plates have also been used, one sheet acting as a "closer" to prevent the tubes from creeping. Three forms of packing are illustrated in Fig. 16. At *a* is shown a cast-iron tube-sheet, the tubes packed with paper packing. The "City of San Francisco" has condenser-tubes packed in this way. Vulcanized fiber makes a very tight packing. At *b* is shown a double-tube sheet, a cast-iron sheet, with a brass following- or closing-sheet. This follower presses down brass rings which encircle the tubes, pressing upon rubber rings which constitute the packing. At *c* is shown the method of packing, with creep-flanged glands screwed into the cast-iron tube-plate. The internal flange restrains the tube from "creeping". In this case the packing used is made of corset lacing. The tubes are commonly of brass, tinned inside, and ½″ to ¾″ in diameter.

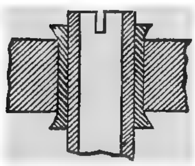


FIG. 15.

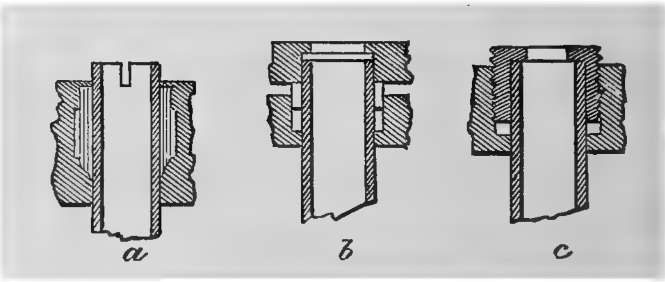


FIG. 16.—CONDENSER TUBE PACKING.

It can hardly be said that the problem of packing condenser tubes has been fully solved until recently. The device of Mr. Frederick M. Wheeler employs two sets of tubes, the large tubes encircling the small with an annular passage for the flow of the water between them. The two sets are secured by screw joints in separate heads at one end of the condenser, and the large tubes being capped and the small tubes open at the opposite end an efficient course of flow is provided. The tubes being entirely free to expand, do away with the trouble of "creeping" and straining the tube joints, which has so long been an annoyance in marine engineering.

The vacuum obtained with surface-condensers is usually $26\frac{1}{2}''$ (equal to about 13 pounds), or $27''$ for large marine condensers, but sometimes this vacuum is exceeded. The keel surface condenser is simply a pipe, or, if more surface is needed, several pipes, which pass outside the vessel, and lay along the keel of the after part. A good vacuum is produced with a smaller surface than is required in proportion to the power for large marine condensers. Its efficiency depends on the speed of the boat. Thus a keel-condenser applied in a small tug of 45 tons obtains a vacuum of $27\frac{1}{2}''$ when running free and only of $24''$ when towing at a low speed.

For large marine surface-condensers the arrangement of the tubes was formerly vertical, but is now in many cases horizontal. Their efficiency depends in some degree upon the course given the condensing-water in passing through the tubes.

Of other forms of condenser the general types may be described as jet- and ejector-condensers. Jet-condensers are mainly employed on river boats, but many large ocean steamers have engines arranged to be used either as surface-condensing or jet-condensing engines. Ejector-condensers of the Morton, Korting, and other types are also used sometimes upon large steamers. The coasting steamer Relief, 338.18 tons, has two $26''$ by $26''$ engines with ejector-condensers. In the injector- or jet-condenser the exhaust-steam passes into a vessel in which it is condensed by the injection of water. In the ejector-condenser the steam is condensed by a cold stream of water impinging upon a jet of steam as it passes out of a nozzle. The vacuum formed gives the fluids an impetus, and the use of an air-pump may be obviated, precisely as a Giffard injector may do the work of a pump in boiler-feeding.

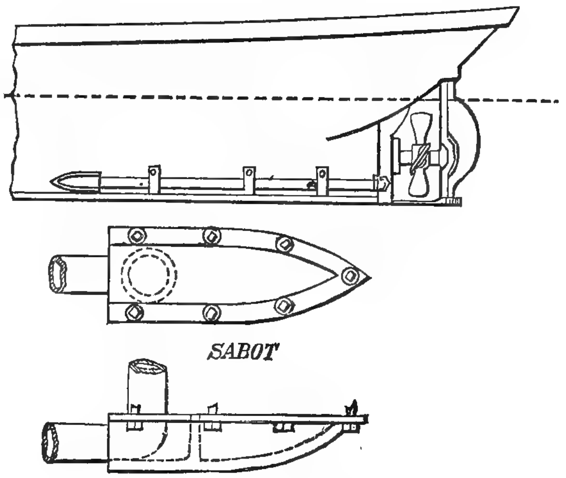


FIG. 17.—KEEL-CONDENSER.

In jet-condensers the vessel in which condensation takes place is sometimes as much as three-fourths the volume of the cylinder. In Watt's original engines it was one-eighth, but is now usually over one-fourth the volume of the steam-cylinder. The area of the injection-valve for admitting water of condensation is taken at $\frac{1}{250}$ of the area of the piston, or $\frac{1}{15}$ of a square inch per cubic foot evaporated by the boiler per hour.

The air-pump, as made by Watt, was one-half the diameter and one-half the stroke of the steam-cylinder. It was thus one-eighth of the volume of the cylinder. According to Rankine the proper volume is one-fifth to one-sixth the volume of the cylinder when single- and one-tenth to one-twelfth when double-acting. This is for jet-condensers.

With the surface-condenser and compound engine the volume of the air-pump (single-acting) is stated to be rated in American practice at about one-twelfth the volume of the low-pressure steam-cylinder, the circulating-pumps having about half the acting capacity of the air-pumps. For jet-condensers larger air-pumps are required than for surface-condensers. We may cite the following examples of relative volumes of cylinders and air-pumps for surface-condensing engines. The great beam-engine of the "Pilgrim" has a cylinder $110''$ by $14'$, air-pump $60''$ by $6'$ stroke of bucket; pump-volume about 25 per cent. of cylinder-volume. The "City of San Francisco" has one $51''$ and $88''$ by $5'$ compound engine and two $24''$ by $2'$ air-pumps; pump-volume about 5 per cent. of the total cylinder-volume and 6 per cent. of the low-pressure cylinder-volume. The little steam yacht "Adelita," with a keel surface-condenser, has two $7''$ by $7''$ cylinders and one $5''$ by $4\frac{1}{2}''$ air-pump; pump-volume about 16 per cent. of the cylinder-volume. All of these air-pumps are as usual single acting.

It should be borne in mind in considering the opening remarks under this head that the introduction of condensers is only one of a number of factors in the improvement of the economy of marine steam service. There are other influences at work which tend to diminish the relative value of condensers. The higher the steam-pressure carried the less relative work can be done by the $13\frac{1}{2}$ or less pounds per square inch due to the vacuum; but this is not the only consideration. Condensers are peculiarly adapted to help out low grades of expansion as well as low steam. With a great expansion permitted by high steam and light service a condenser might become a worse than useless adjunct. This point has not been reached in marine service, but we can see that the advantages which were very great under 20 or 30 pounds boiler-pressure will have dwindled considerably under 150 pounds boiler-pressure.

BOILERS OF STEAMERS IN FOREIGN TRADE.

Each of the transatlantic steamers of the American Steamship Company has three compound cylindrical return-tubular boilers, double-ended, and fired fore and aft. Each boiler is 12′ 3″ in diameter by 17′ long, and contains six furnaces, three in each end. Each furnace is 2′ 10″ in diameter, grate-bars 5′ 4″ long. Each boiler has three hundred and sixteen 3″ tubes 7′ long.

Of steamers running to Panama, West Indies, and South America, the following examples of boilers may be cited:

The "United States," 1,180.10 tons, plying from Boston to Havana (and also to Halifax, Nova Scotia) has two rectangular return-tubular boilers 16′ wide and 16½′ long. The "City of Vera Cruz," 1,874.36 tons, of the New York and Havana Mail Steamship Company's line, has vertical boilers, two in number, and each 13′ in diameter by 19′ 10″ high. The employment of such large vertical boilers is unusual in marine service, but their use is said to have been attended with perfect success. Large vertical boilers are not commonly employed even in stationary service (although the Baldwin Locomotive Works have a number of considerable size), but in land service their use is mainly confined to portables and in marine service to small yacht and tug-boat engines. Of one of the boilers of the "Vera Cruz" a plan and an elevation looking forward are given in Fig. 18. Furnace-stays are not shown in the plan. The tubes are 11′ long, 8′ wetted length, and there are 5,290′ heating service for both boilers taken together. The furnaces are full 4′ high, giving ample space for combustion. There are four hundred and seventy-two 2½″ tubes. The temperature at the base of the funnel is about 400° Fahr. These peculiar boilers were designed by Mr. Peek and built by Quintard & Murphy, New York. The "City of Merida," 1,492.45 tons, running to Vera Cruz, has two return-tubular boilers, built by C. H. Delamater & Co. These are each 15′ in diameter by 16′ long, containing two hundred and fifty-four 3½″ tubes.

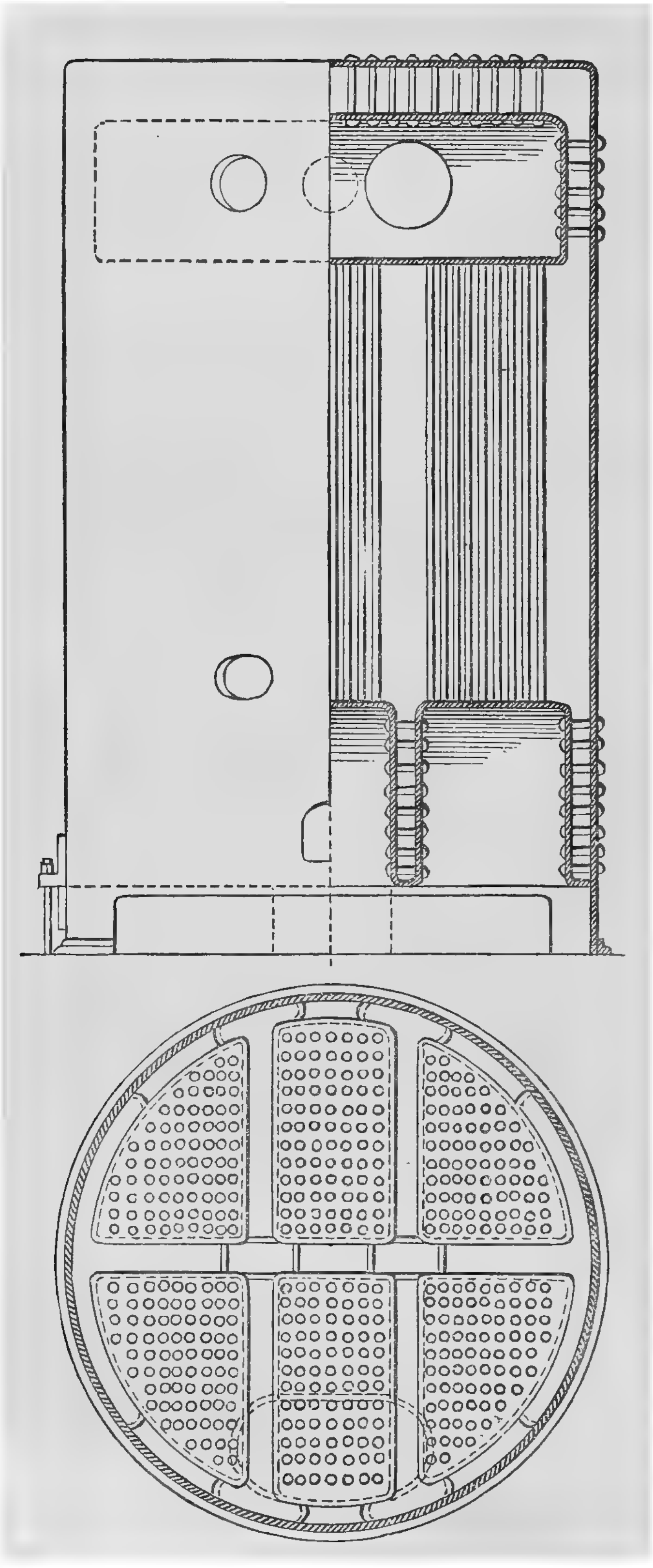


Fig. 18.

The "City of Para," 3,532.25 tons, has six return-tubular boilers 13′ 1¼″ diameter, 10½′ long; each boiler has two hundred and four 3¼″ tubes. The steam-pipe is of copper 12″ in diameter. The aggregate safety-valve area is 170 square inches. A donkey boiler is also employed. The "Newport," 2,735.29 tons, has six return-tubular boilers, each 13′ 5″ diameter by 11 long. Each boiler has three 3½′ flues and two hundred and thirty-one 3¼″ tubes. The aggregate safety-valve area is 197¾ square inches. The "City of Alexandria" has four cylindrical return-tubular boilers, each 14′ 6″ in diameter and 11′ long.

The "Tropic," 379.77 tons, plying from Philadelphia, has one return-tubular boiler 10½′ in diameter by 10½′ long. The "Acadia," 955.58 tons, has two vertical tubular boilers, each 7′ in diameter and 12′ 5″ high.

The "Margaret," 508.05 tons, plying between New Orleans and Havana, has one 8½′ by 20′ cylindrical tubular boiler, and the "E. B. Ward, Jr.," 387.92 tons, has one fire-box and return-tubular boiler 10′ in diameter and 18′ long.

For some of the above-mentioned steamers the gross boiler-volumes are given with the ratios per ton of vessel:

Name.	Boiler-volume.	Per ton of vessel.	Boiler-pressure allowed.	Name.	Boiler-volume.	Per ton of vessel.	Boiler-pressure allowed.
	Cubic feet.		*Pounds.*		*Cubic feet.*		*Pounds.*
Pennsylvania	6,011.61	1.93	64	City of Alexandria	7,216.32	2.93	80
City of Vera Cruz	5,265.08	2.81	70	Tropic	909.21	2.39	35
City of Merida	5,655.36	3.78	40	Acadia	955.58	2.47	40
City of Para	8,491.74	2.42	80	Margaret	1,134.88	2.23	35
Newport	9,199.08	3.36	80	E. B. Ward, Jr	1,413.72	3.64	40

The "City of Washington," 2,618.27 tons, plying between New York and Havana, has two vertical tubular boilers 18′ in diameter, and 18′ 6″ high. These have an aggregate boiler-volume of 9,416.50 cubic feet, or more than any other steamer inspected at New York. The boiler capacity is thus ample, and the steamship is one of the swiftest going out of New York. The "Louisiana," of the Cromwell line (New York and New Orleans), the swiftest steamship flying the American flag, has boilers of peculiar design, which will be elsewhere described. The prevailing type of boiler is the return-tubular, sometimes fired fore and aft, as in the steamships of the American line (in which case the boilers are set with their length parallel to that of the vessel), but more generally with the fire-room in the center of the vessel, and the boilers, which are comparatively short, placed in sets of pairs, across, and one on each side of the vessel.

The time has been when the variety of boilers employed in American marine service was so numerous that the exception may almost be said to have been the rule, and there is now much greater uniformity in practice.

The following details are given of a return-tubular boiler of the outside dimensions: Length, 14′ 6″; breadth, 8′ 6″; depth, 9′. Such a boiler might be more fully specified as a compound, rectangular, direct-flue, and return-tubular boiler. A boiler is compound when, as in most large marine boilers, and in most boilers of large diameter in any service, there are several furnaces in each boiler. The boiler in question has two furnaces, and is one of a pair which are set as, is said, right and left, one on each side of the steamship. It has four 11″ and two 18″ flues, 5′ 6″ long, and sixty-four 4½″ tubes, 12′ long. The grate is 3′ 6″ wide, and 6′ long, or nearly half the length of the boiler. The safety-valve is 5½″ in diameter. The grate-surface is 42 square feet; heating-surface, 1,248 square feet; gross volume, 1,109.25 cubic feet. The ratio of heating surface to volume is 1.11; of heating- to grate-surface, 29.71.

The following discussion of the capacities of large marine boilers, and of their capacities relative to the capacities of condensers and compound-engines, will be found of general application, although the data are drawn from foreign sources.

BOILER AND ENGINE CAPACITIES OF OCEAN STEAMERS.

Some exception may be taken to the method of stating boiler capacities by the cubic volume of the boiler-cylinders, which has been the measure of boiler capacity presented by aggregates and averages for the several districts and classes of steamers. The usual measure of capacity for a boiler is the heating-surface below the water-line (neglecting superheating surface), and in ordinary practice 8 to 16 square feet of heating-surface are calculated for a nominal horse-power. With the great variety of styles and dimensions existing among marine boilers, it has not been practicable to calculate the heating-surface in every case. But the simple measure of capacity given—the boiler-volume—may easily be compared with the heating-surface in a sufficient number of cases to guide the reader to an approximation of the latter quantity in any case.

It must be said, however, that while area of heating-surface is the usual measure of steaming performance, it is by no means an exact measure even for similar construction of boilers. In evidence of this, I may cite Mr. F. C. Marshall's table of the data of long ocean voyages of English steamers. Thirty cases of as many steamships are cited in the order of economy of coal per indicated horse-power of engines, the range being from 1½ to 2¼ pounds coal per horse-power per hour:

COAL.	HEATING-SURFACE OF BOILERS.		COAL.	HEATING-SURFACE OF BOILERS.		COAL.	HEATING-SURFACE OF BOILERS.	
Per indicated horse-power per hour.	Per indicated horse-power.	Per pound coal per hour.	Per indicated horse-power per hour.	Per indicated horse-power.	Per pound coal per hour.	Per indicated horse-power per hour.	Per indicated horse-power.	Per pound coal per hour.
1.50	4.68	3.12	1.76	4.76	2.69	1.90	3.35	1.762
1.60	3.19	1.99	1.76	3.97	2.27	1.90	3.56	1.873
1.63	3.70	2.26	1.763	4.35	2.46	1.90	4.45	2.34
1.66	3.55	2.14	1.80	5.52	3.065	1.90	4.90	2.58
1.67	3.34	2.00	1.83	3.37	1.839	1.93	3.28	1.70
1.67	2.88	1.725	1.84	4.34	2.36	1.945	4 59	2.36
1.69	3.98	2.35	1.85	3.11	1.647	2.00	2.89	1.44
1.70	4.91	2.88	1.85	4.19	2.26	2.125	2.80	1.315
1.70	6.24	3.705	1.87	4.39	2.35	2.25	2.80	1.243
1.72	4.01	2.34	1.89	3.86	2.05	2.25	2,77	1.23

In this connection I present a diagram, comparing some of the relations between the data of ten of these steamers, and if there be any rule of application discoverable from the comparison, it must be of utility in American as well as in English practice.

This diagram is explained as follows: The ten vertical dotted lines are representative of ten English ocean steamships of which the data were published in the London *Engineering*. They are arranged in order of economy of coal consumption from left to right. The line A, taken as a base line, represents the data charted for the most economical engine, with which the others are compared. The cross-lines B, C, and D represent the areas of grate-, condensing-, and heating-surface per indicated horse-power cited by Mr. Marshall as embodying the best practice.

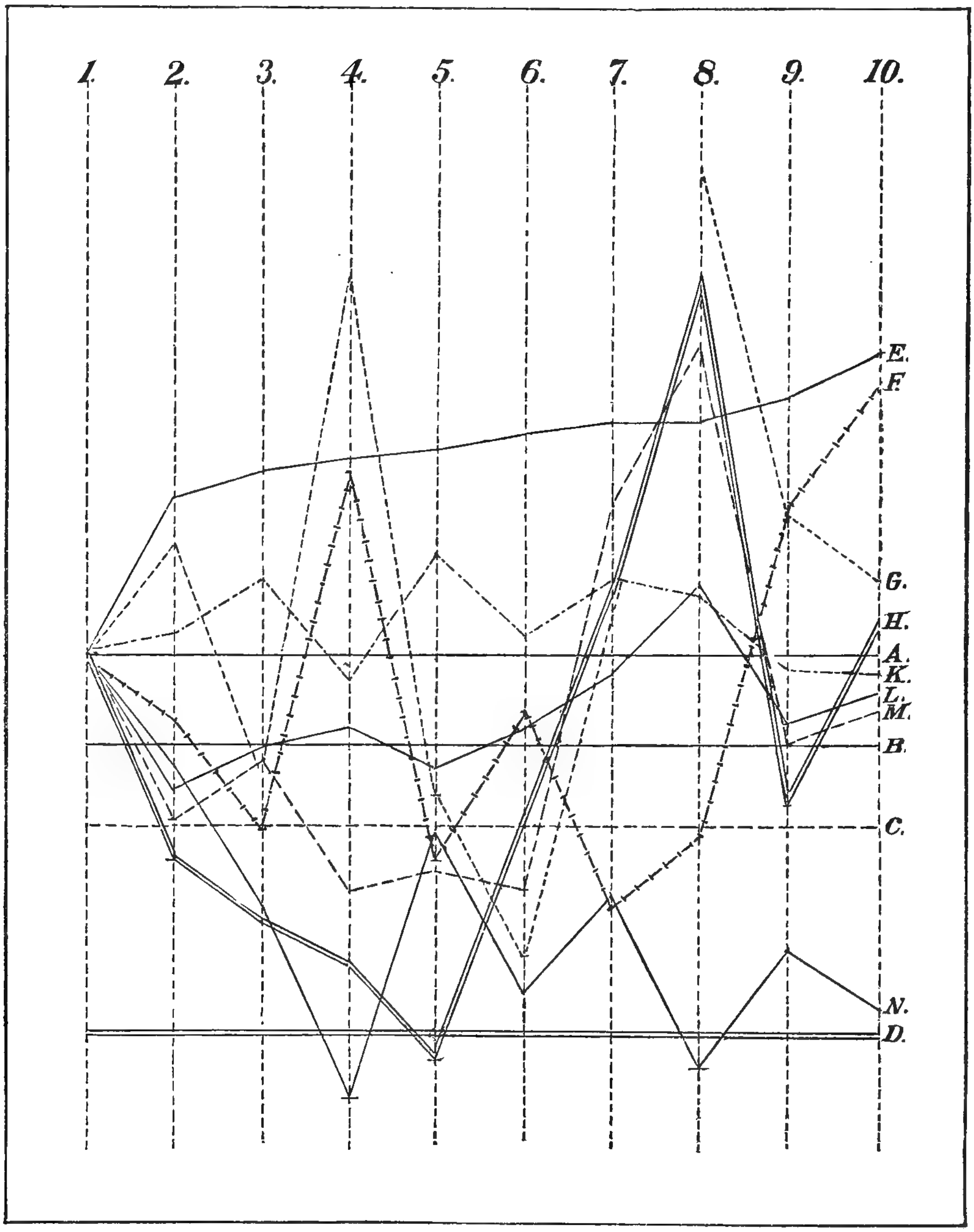


FIG. 19.

These areas are 0.11 square foot of grate-, 2 square feet of condensing-, and 3 square feet of heating-surface per indicated horse-power. They are shown in comparison not with each other but to different scales, being compared with like data of the most efficient engine cited, viz, 0.15 square foot of grate-, 2.73 square feet of condensing-, and 4.68 square feet of heating-surface. The data charted for the other engines are compared with those of the first in like manner, and the points determined on the vertical lines are connected by joining lines, with the idea of exhibiting progressive series of the several data attendant upon a requirement of fuel progressing from $1\frac{1}{2}$ to $1\frac{3}{4}$ pounds coal per indicated horse-power per hour. The line E indicates the coal consumption per indicated horse-power per hour, viz, 1.50 pounds (the base line), 1.63 pounds, 1.66 pounds, 1.67 pounds, 1.67 pounds, 1.69 pounds, 1.7 pounds, 1.7 pounds, 1.72 pounds, and 1.76 pounds, respectively. The line F indicates the inches diameter of screw

per indicated horse-power, viz, 0.20 (the base line), 0.17, 0.10, 0.31, 0.08, 0.17, 0.09, 0.12, 0.26, 0.32, respectively. Too large a screw is sometimes said to "lock up" an engine, or to reduce its power. Thus an 18′ 10½″ screw may be said to "lock up" a 3,000 horse-power engine to 2,000 horse-power, or, in other words, to prevent the engine from being speeded up to the higher power, precisely as speed is limited in driving paddle-wheels or in doing any work against resistances. To be sure the engine may perhaps be run economically at a low speed, but if speed be permanently reduced there remain unnecessarily large areas of the heating and other essential surfaces so that the steam machinery is much heavier and more costly than necessary. The line H indicates the heating-surface per indicated horse-power, viz, 4.68 (the base line), 3.70, 3.55, 3.34, 2.88, 3.98, 4.91, 6.29, 4.01, and 4.76 square feet, respectively. The line G indicates the product of boiler-volume into pressure per indicated horse-power, viz, 262 (the base line), 288, 238, 344, 232, 196, 272, 367, 292, and 279. The line K indicates the absolute indicated horse-powers, viz, 900 (the base line), 1,200, 2,200, 420, 2,677, 1,200, 2,207, 1,801, 650, and 500 indicated horse-power, respectively. The line L indicates the grate-surface per indicated horse-power, viz, 0.15 of a square foot (the base line), 0.09, 0.11, 0.12, 0.10, 0.12, 0.14, 0.18, 0.11, and 0.13 of a square foot respectively. The line M indicates the condensing-surface per indicated horse-power, viz, 2.73 square feet (the base line), 2, 2.27, 1.67, 1.81, 1.66, 3.36, 4.12, 2.33, and 2.50 square feet, respectively. Lastly, the line N represents the ratio of tube-surface to furnace-surface in the whole heating-surface, viz, 6.98 (the base line), 6.09, 4.65, 3.10, 5.48, 4.01, 4.84, 3.35, 4.34, and 3.87. It may be noted that the areas of grate-, condensing-, and heating-surface stated as embodying the best practice are nearly minima of the examples cited, from which it may be said that the most effective areas may be considerably increased without seriously affecting the efficiency of the engine, and, above these effective areas, it will be seen from the diagram that widely varying ratios of proportionment between these areas may exist without reference to the efficiency. Liberal proportions may effect a saving by wider adaptability to varying conditions, as, for example, when the fires are forced. But beyond a certain ill-defined point the influences of loss due to cylinder condensation and radiation of heat, the wastefulness of too light loads, and redundant heating-surfaces begin to show themselves in the coal-bunkers. In first cost per horse-power the difference between the engines cited is very great, the excessively large engines costing about twice as much per horse-power as those more closely proportioned to the demands put upon them. To provide for variations of draught and speed, for differences in fuel, stoking, heat of fire, boiler encrustation, and other contingencies, it may not be advisable to skimp proportions very closely, much less to seek for any commercial economy beyond the best engineering economy; but to put in 20 tons of engines and boilers where 10 tons would do as good duty is certainly a foolish though not altogether an unexampled waste of capital.

A comparison of the heating-surfaces and boiler-volumes of the 10 marine engines cited is as follows:

Per indicated horse-power.		Ratio, surface to volume.	Per indicated horse-power.		Ratio, surface to volume.
Heating-surface.	Boiler-volume.		Heating-surface.	Boiler-volume.	
Square feet.	*Cubic feet.*		*Square feet.*	*Cubic feet.*	
4.68	3.75	1.25	3.98	2.19	1.81
3.70	3.20	1.16	4.91	3.63	1.35
3.55	2.97	1.19	6.29	4.45	1.41
3.34	3.44	0.97	4.01	3.65	1.10
2.88	3.23	0.89	4.76	3.55	1.34

The volumes exhibit less variation per horse-power than do the surfaces, the extreme variation being 103 per cent. for the former to 118 per cent. for the latter, and the extreme variation from the average being 1.22 in the former against 2.08 in the latter.

The data of the ten engines are here given as an illustration of the best English practice. Whatever we may say of rule-of-thumb methods while we consider the variations in proportion of the essential areas, we must admit that the results, ranging from 1½ to 1¾ pounds coal per horse-power per hour, are of the very best:

1. Cylinders, 34″ and 61″ by 45″ stroke; 450′ piston speed per minute; 2,466 square feet condensing-surface; 15′ 3″ diameter screw; 70 pounds boiler-pressure; two boilers 12′ shell by 15′ long, with eight furnaces, each 3′ 6″ in diameter; eight hundred 3″ tubes 6′ long; grate-surface, 140 square feet; heating-surface, tubes 3,688 square feet, furnace and boxes 528 square feet, total 4,216 square feet; coal in twenty-four hours, 14.5 gross tons (32,400 pounds); heating-surface per pound coal per hour, 3.12 square feet.

2. Cylinders, 35″ and 70″ by 48″ stroke; 400′ piston speed; 2,400 square feet condensing-surface; 17′ diameter screw; 90 pounds boiler-pressure; two boilers 11′ 6″ shell by 18′ 6″ long, with eight furnaces, each 3′ 6″ in diameter, six hundred and forty 3½″ tubes 6′ 10″ long; grate-surface, 160 square feet; heating-surface, tubes 3,814, furnace and boxes 626, total 4,440 square feet; coal in twenty-four hours, 21 tons (gross); heating-surface per pound coal per hour, 2.26 square feet.

3. Cylinders, 46″ and 87″ by 57″ stroke; 484′ piston speed; 5,000 square feet condensing-surface; 19′ diameter screw; 80 pounds boiler-pressure; three boilers 12′ 3″ shell by 18′ 6″ long, with twelve furnaces, each 3′ 9″ in diameter, one thousand one hundred and sixty-four 3¼″ tubes 6′ 7″ long; grate-surface, 250 square feet; heating-surface, tubes 6,420, furnace and boxes 1,383, total 7,803 square feet; coal in twenty-four hours, 40 tons; heating-surface per pound coal per hour, 2.14 square feet.

4. Cylinders, 22″ and 44″ by 30″ stroke; 360′ piston speed; 705 square feet condensing-surface; 11′ diameter screw; 100 pounds boiler-pressure; one boiler 12′ 8″ shell by 11′ 6″ long, with three furnaces, each 3′ in diameter, one hundred and seventy-two 3¼″ tubes 7′ 3″ long; grate-surface, 49½ square feet; heating-surface, tubes 1,060, furnace and boxes 342, total 1,402 square feet; coal in twenty-four hours, 7½ tons; heating-surface per pound coal per hour, 2 square feet.

5. Cylinders, 50″ and 86″ by 54″ stroke; 540′ piston speed; 4,865 square feet condensing-surface; 17′ 6″ diameter screw; 72 pounds boiler-pressure; four boilers, each 13′ 4½″ wide, 16′ ¾″ high, 10′ ¾″ long, with twelve furnaces, each 3′ 6″ in diameter, one thousand and twenty-four 3½″ tubes 7′ long; grate-surface, 273 square feet; heating-surface, tubes 6,530, furnace and boxes 1,192, total 7,722 square feet; 48 tons coal in twenty-four hours.

6. Cylinders, 35″ and 70″ by 48″; 424′ piston speed; 2,000 square feet condensing-surface; 17 feet diameter screw; 90 pounds boiler-pressure; two boilers 9′ 6″ shell by 18′ 6″ long, with eight furnaces, each 3′ 6″ in diameter, six hundred and eight 3½″ tubes 6′ 10⅜″ long; grate-surface, 150 square feet; heating-surface, tubes 3,822, furnace and boxes 952, total 4,774 square feet; 21½ tons coal in twenty-four hours.

7. Cylinders, 54″ and 94″ by 60″ stroke; 530′ piston speed; 7,420 square feet condensing-surface; 18′ 3½″ diameter screw; 75 pounds boiler-pressure; six boilers 12′ 9″ shell by 10′ 6″ long, with eighteen furnaces, each 3′ 2″ in diameter, one thousand three hundred and eight 3½″ tubes 7′ 6″ long; grate-surface, 313 square feet; heating-surface, tubes 8,983, furnace and boxes 1,856, total 10,839 square feet; 40.3 tons coal in twenty-four hours.

8. Cylinders, 54″ and 94″ by 60″ stroke; 486′ piston speed; 7,422 square feet condensing-surface; 18′ diameter screw; 82½ pounds boiler-pressure; six boilers 12′ 9″ shell by 10′ 6″ long, with eighteen furnaces, each 3′ 2″ in diameter, one thousand two hundred and sixty-six 3½″ tubes 7′ 6″ long; grate-surface, 324 square feet; heating-surface, tubes 8,735, furnace and boxes 2,605, total 11,340 square feet; 32.8 tons coal in twenty-four hours.

9. Cylinders, 30″ and 58″ by 39″ stroke; 400′ piston speed; 1,518 square feet condensing-surface; 14′ 2″ diameter screw; 80 pounds boiler-pressure; two boilers 12′ shell by 10′ 6″ diameter, with four furnaces, each 3′ 2″ in diameter, three hundred and forty-four 3¼″ tubes 7′ 3″ long; grate-surface, 69.64 square feet; heating-surface, tubes 2,120, furnace and boxes 488, total 2,608 square feet; 12 tons coal in twenty-four hours.

10. Cylinders, 29″ and 56″ by 33″ stroke; 350′ piston speed; 1,250 square feet condensing-surface; 13′ 3″ diameter screw; 70 pounds boiler-pressure; two boilers 11′ shell 10′ 6″ long, with four furnaces, each 3′ in diameter, three hundred and sixteen 3¼″ tubes 7′ ½″ long; grate-surface, 66 square feet; heating-surface, tubes 1,891, furnace and boxes 488, total 2,379 square feet; 9½ tons coal in twenty-four hours.

BOILERS OF NEW ENGLAND STEAMERS.

Of 85 boilers in vessels of class I, 82 are return-tubular, and 3 return-flue, though many of the boilers have direct flues. Ten are rectangular and 75 cylindrical. The boilers are invariably of large diameter, being in several cases deeper than the hold of the boat itself. In only one boat is a boiler-pressure of over 40 pounds allowed. In this 80 pounds per square inch is allowed, the boiler being 11 feet in diameter, with a shell 0″.692 thick. For the low-pressure boilers the most usual thickness of shell is ⅜″. The smallest diameter of boiler is 8′ 9″, and diameters above 13 feet are exceptional. The average pressure allowed is about 32 pounds. There is is one set of 6 boilers, two of 4, four of 3, and twenty-three of 2 boilers per vessel, the rest being used singly. The "Decatur H. Miller,' plying between Baltimore and Boston, has four return-tubular boilers, each 11′ in diameter by 11′ long.

Of the pressures allowed in the boilers of smaller vessels, the following table will exhibit the range. The extreme high pressures are allowed for coil-boilers, but one horizontal tubular boiler, 2½ feet diameter by 4 feet long, and two vertical tubular steel boilers are allowed a pressure of 150 pounds.

[Pressure allowed in pounds per square inch.]

	CLASS II.			CLASS III.			CLASS IV.			CLASS V.			CLASS VI.		
	Highest.	Average.	Lowest.	Highest.	Average.	Lowest.	Highest.	Average.	Lowest.	Highest.	Average.	Lowest.	Highest.	Average.	Lowest.
Portland	33	31	30	100	55	30	90	76	40	100	78	60	150	97	70
Boston	40	34	23	100	58	25	90	80	50	124	80	60	150	94	70
New London	45	38	30	100	53	25	170	79	40	173	84	40	160	100	65

STEEL BOILERS.

Of steel boilers there are comparatively few. In Class I there is a set of six boilers, partly of steel, upon the steamship "Massachusetts." In Class II there are no steel boilers; in Class III, 3; in Class IV, 1; in Class V, 4; and in Class VI, 16. Of these 30 boilers, 19 are vertical tubular, 1 direct horizontal tubular, 1 return-flue, and 9 return-tubular boilers.

FLUE-BOILERS.

The return-tubular boilers, often with direct flues, are the prevailing type of marine boiler used in New England and upon the whole Atlantic seaboard, excepting for the smallest classes of steamers, in which vertical tubular boilers are more commonly used. Direct flues for return-tubular boilers often help to increase the heating-surface, as well as having a utility similar to that of combustion-chambers, but the employment of flues differs greatly from what it has been in the past. What may be called the experimental period in marine steam service was characterized by the use of flue-boilers in a great variety of designs, of which few have survived. This was also true of English practice. "The variety of forms and arrangements of flues in marine boilers," wrote Rankine, "is such as to defy classification." Some of the American designs of built-up flue-boilers peculiar to this period are described in *Marine Engines of the United States*, by B. H. Bartol, published at Philadelphia, 1851. Their peculiar arrangements of flues were designed to obtain a great amount of heating-surface, but usually without due regard for the requirements of draft and the all-important condition of accessibility to interior parts for cleaning and repairs. Some of the peculiar malformations of these flue-boilers appear to have been mere caprices of the draughting-room, as useless as fifth wheels to a coach or cog-drivers for a locomotive, but of great advantage to the boiler-making trade on account of the complexity of the work involved. This required a great deal of flange-turning, the most highly skilled work upon a boiler. The introduction of tubes and the use of simpler designs of boilers has changed all this, eliminating the greatest and most difficult portions of the flange-turning and making straight work, requiring less skill, and insuring safer results in the product.

BOILERS OF THE SMALLER STEAMERS.

Of 32 boilers on vessels of Class II, 18 are return-tubular and 14 drop-flue and return-flue boilers.

Of the less usual types on New England steamers, we find 1 rectangular boiler, 1 small vertical water-tube boiler, 1 plain cylindrical boiler, 1 combined coil and vertical tubular boiler, and 1 vertical tubular boiler with return-tubes. There are 17 coil-boilers. Of comparatively large boilers, the drop double return-flue boilers are a common type. There are about 20 horizontal tubular boilers of the locomotive type, with fire-boxes. But the great preponderance of return and vertical tubular boilers is shown by percentages of all in the classes specified as follows:

Description.	Class III.	Class IV.	Class V.	Class VI.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Return tubular	65	64	56	19
Vertical tubular.....	[illegible]	26	30	62

Below Class II boilers are used singly, with the exception of one vessel, which has a pair of boilers. In return-tubular boilers, the length is commonly twice the diameter, but drop-flue and direct tubular boilers are relatively longer, the length often being three or four times the diameter. In the vertical tubular boilers the height is usually less than twice the diameter. It is stated by Professor Thurston that the vertical was the first form of tubular boiler, being invented in 1791 by Nathan Read, of Salem.

COIL-BOILERS.

There are in New England the following steamers with coil boilers. These are omitted from the lists of aggregates and averages, because the boiler capacities can not be considered in the same way:

Inspected at New London: One steamer, 62.09 tons; 1 compound engine, 3.54 cubic feet. One steamer, 48.20 tons; 1 engine, 2.75 cubic feet. Thirteen steamers, about 66 tons; 16 engines, 1.5 cubic feet.

Inspected at Boston: Two steamers, 6 tons; 2 engines, 0.05 cubic feet.

Coil-boilers have the advantages of being light in weight, carrying high pressure, and getting up steam with great rapidity, added to which, like sectional boilers, they give a high degree of security against explosion. Most

of those in the service are of the Herreshoff type, of which a sectional view (Fig. 20) is given. The operation of this boiler may be briefly described. The feed-water is pumped through a spiral coil, A B, which, starting at the top of a furnace, forms an almost cylindrical combustion-chamber. As the water nears the grate (the heat becoming more intense) it is partly converted into steam, and is passed into a separator, D, from which the dry steam is carried through a coil (G), which is wound about the crown of the furnace, finally delivering its superheated steam to the engine The water carried to the separator is returned to the coil, or may be blown to waste if desired. The following example of the use of this form of boiler may be noted.

A Spanish gunboat, 135 feet long, has engines indicating 400 horse-power and a Herreshoff boiler with 84″ diameter of grate and 550′ of pipe, varying in diameter from 4″ to $2\frac{1}{2}$″ (largest at the bottom of furnace), the coil being put together in four sections, with right and left couplings. Speed of gunboat, $16\frac{1}{2}$ miles an hour.

The United States torpedo launch "Lightning": Length, 58 feet; speed, 20.34 miles an hour. Driven by a

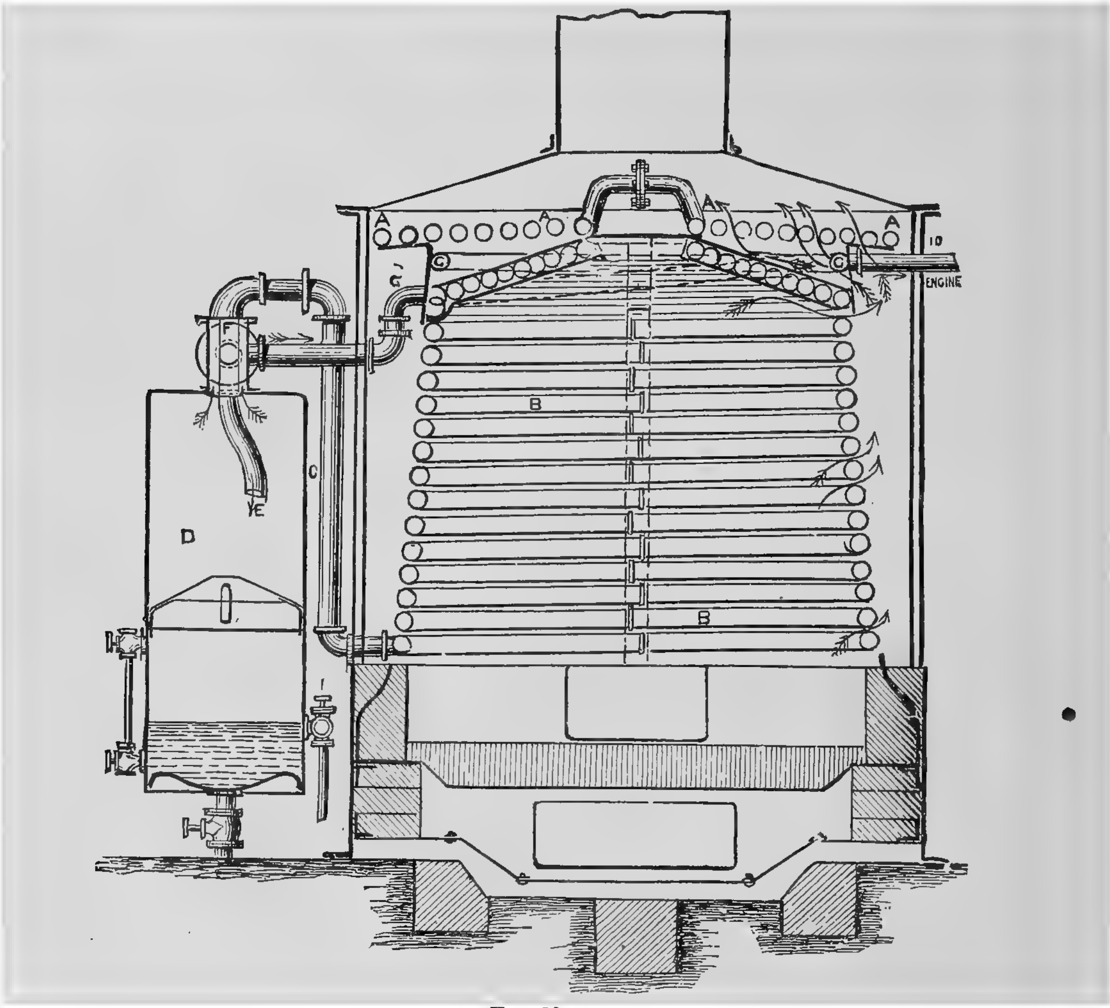


FIG. 20.

pair of 5″ by 10″ engines, with a Herreshoff boiler, 44″ grate; 130 square feet of heating-surface in the coil. The weight of this boiler was 1,500 pounds. Steam has been raised from 100 to 160 pounds within two minutes.

I give a few examples comparing the use of coil-boilers with vertical tubular boilers: The "Gleam," of Bristol, Rhode Island, is a boat of 62.09 tons, 108 feet long, 15.5 feet broad, 6.7 feet deep. It has a compound engine; cylinders, $10\frac{1}{2}$″ and 18″; stroke, 18″, with pipe-condenser. It has a coil-boiler of 3″, $2\frac{1}{2}$″, 2″, and $1\frac{1}{2}$″ pipe; total length of pipe, 750 feet; steam-pressure allowed, 170 pounds. "The Favorite," of Norwich, Connecticut, is a boat of 73.99 tons, 115 feet long, 16 feet broad, $5\frac{3}{4}$ feet deep. It has a $16\frac{5}{16}$″ by 16″ non-condensing engine and a vertical tubular boiler $5\frac{1}{2}$′ diameter and $10\frac{1}{2}$′ high; boiler-pressure, 75 pounds.

On the "Clipper," a small boat, 24 feet long, $5\frac{1}{2}$ feet broad, and $2\frac{1}{2}$ feet deep, plying on the upper waters of the Connecticut river, a coil of $\frac{3}{4}$″ pipe, 90′ long, is used, the engine being $3\frac{3}{4}$″ by 4″ stroke, and non-condensing; 100 pounds boiler-pressure is allowed. The "Hub," a boat 22 feet long, 5 feet broad, and $2\frac{1}{2}$ feet deep, plying on the Merrimac river, has a $2\frac{7}{8}$″ by 4″ (stroke) engine, and a coil-boiler of 1″ pipe; length of pipe, 80′; thickness, $\frac{1}{8}$″; pressure allowed, 100 pounds. On similar small boats, vertical tubular boilers 2′ in diameter by 3′ high are used.

The Herreshoff boiler on the steam yacht "Leila," whose engines are elsewhere described, contains 654′ in length of pipe, of a diameter (outside) ranging from 1⅞″ to 3½″. The interior heating-surface of the pipe is 411½ square feet, its exterior surface being 485 square feet. The furnace and boiler is about 7′ in diameter by 7′ high, these being the dimensions of the enclosing (fire) shell.

An ingenious type of coil-boiler in process of introduction in this district is the Trowbridge boiler with forced circulation, by which the water is kept flowing continuously through a circuit of coiled pipe. This differs from the Herreshoff boiler, the water being circulated by a pump and a certain water-level being maintained in the stand-pipe from which the steam is drawn. This level is preserved by an automatic feeding device, designed by Mr. T. W. Mather, and consisting of two pumps, one of which operates to withdraw water from the boiler if the level be too high, while the other supplies water when the level is too low. The feed is thus automatic and takes care of itself. The furnace is practically a base-burning stove and requires little attention. The boiler evaporates 8½ pounds water per pound coal at a rate of combustion of 46½ pounds per square foot of grate per hour, and nearly 9 pounds at a rate of 25 pounds per square foot of grate per hour. A 5-horse-power boiler weighs about half as much as a 5-horse-power boiler of the ordinary cylindrical tubular style. It gets up steam enough to drive an engine of 5 horse-power in nine minutes or less, under ordinary conditions.

BOILERS OF ALBANY STEAMERS.

CLASS I: Of 14 boilers 3 are specified as drop return-flue, 2 as return-flue, 9 as return-tubular. These are used in sets of 2 and 3. The "Thomas Cornell," 1,160.85 tons, has two return-tubular boilers each 12′ in diameter by 25′ long. The boilers of the "City of Troy" are return-tubular, 11′ in diameter by 21′ 3″ long. The "Albany" has three drop return-flue boilers each 8′ 9″ in diameter by 33′ long. The "City of Catskill" has two return-flue boilers each 8′ 6″ diameter by 25′ long. The boiler front is 9′ 6″ wide. Forty pounds is the usual maximum pressure.

CLASS II: Of 26 boilers 8 are specified as Redfield flue-boilers, 1 is a double-return flue-boiler and 17 are return-tubular boilers. The only steel boilers in the class are two return-tubular boilers each 10′ in diameter and 25′ long, upon the "Mary Powell." There are no steel boilers on vessels of the preceding class.

Of all the steamers in the Albany district the following nine have, in the order stated, the largest boiler-volumes:

The "Thomas Cornell," 1,160.85 tons, plying between New York and Rondout, two 12′ by 25′ return-tubular boilers.
The "Albany," 1,346.53 tons, plying between New York and Albany, three 8¾′ by 33′ drop return-flue boilers.
The "Chauncey Vibbard," 1,066.98 tons, plying between New York and Albany, three 8′ by 31′ return-tubular boilers. Instead of as usual having the furnaces of the boilers discharge the products of combustion through one or two smoke-stacks, this steamer is peculiar in having a smoke-stack for each boiler, three abreast across the vessel.
The "Connecticut," 728.79 tons, plying between New York and Albany, two 11′ by 22′ return-tubular boilers.
The "Saratoga," 1,438.75 tons, plying between New York and Troy, two 11′ by 21⅛′ return tubular boilers.
The "City of Troy," 1,527.83 tons, plying between New York and Troy, two 11′ by 21¼′ return-tubular boilers.
The "Mary Powell," 983.57 tons, plying between Rondout and New York, two 10′ by 25′ return-tubular boilers.
The "Cornelius Vanderbilt," 689.81 tons, plying upon the Hudson river, two 10$\frac{7}{12}$′ by 21′ return-tubular boilers.
The "John Marshall," 330.37 tons, plying upon any inland route, has one return-tubular boiler 13′ by 24′. This boat, which has so large a boiler-volume in proportion to its tonnage, is a towing-boat, the others being passenger-boats.

We naturally expect the boiler capacity to vary without regard to the tonnage and according to the speed of vessel and character of service, but the boiler-volumes and cylinder-volumes have no close proportion, as may be seen from the following examples taken from steamers of Class II:

Kind of engine.	Stroke of engine.	Cylinder-volume.	Boiler-volume.	Pressure allowed.
	Feet.	*Cubic feet.*	*Cubic feet.*	*Pounds.*
Vertical direct-acting condensing-engine	3	23.60	1,731.84	35
Do	3.8	31.93	1,657.38	46
Beam condensing-engine	10	105.56	1,909.71	30
Do	10	209.12	1,047.63	45
Do	12	339.29	4,181.46	35

The Redfield boiler is described as "a set of plain flue or tubular boilers, such as used for stationary purposes, connected at front and back and surrounded on the sides by a water-shell, which is strongly braced, and takes the place of brickwork as commonly used on stationary boilers".

CLASS III: Of 44 boilers 12 are specified as return flue, 3 as drop return-flue, 21 as Redfield flue, and only 7 as return-tubular boilers. There is also 1 fire-box tubular boiler. The Redfield boilers are in sets of 2 or 3, except in one instance. All the other boilers are used singly. The fire-box boiler mentioned (10′ 9″ diameter, 24′ 6″ long) is upon the "George A. Hoyt," a towing-boat. The drop return-flue boilers are a common ferry-boat type.

The "John Adams," Albany and Greenbush ferry, has such a boiler, 9′ 6″ by 24′ long. All of these boilers have cylindrical shells, and the diameter and length of shell are to be understood as the dimensions specified. The Redfield boilers are nearly all upon steamers plying between New York and Albany. The "Ontario" has three, each 3½′ by 28′; the Cayuga three, each 6½′ by 28′; the Anna one, 8′ by 20⅔′. The usual pressure allowed is 35 pounds.

CLASS IV: Of 20 boilers 19 are cylindrical and 1 is rectangular; 6 are return-flue, 3 fire-box or locomotive, and 11 return-tubular. There are no steel boilers either in this or in the preceding class. The locomotive-boilers are of small diameter. The Rondout ferry-boat "Riverside," 51.60 tons, has one locomotive-boiler 30″ diameter by 12′ 6″ long. This is exceptional. Two locomotive-boilers on the "Compeer," each 3′ by 7′, are allowed to carry 100 pounds pressure. The "L. P. Smith," canal-boat, has one 4′ 3″ by 9′ 6″ (long) return-tubular boiler.

CLASS V: Of 25 boilers 3 are of the locomotive, 1 of the vertical tubular, and 21 of the return-tubular type. The vertical tubular boiler is on the yacht "Dashaway." The locomotive-boilers are upon the yacht "Bessie" and the tug-boats "Charles P. Grout" and "John S. Ide." There are no steel boilers. Nearly all of the steamers are tug-boats.

CLASS VI: Of 67 boilers 22 are vertical and special tubular boilers commonly used upon steam yachts, 8 are locomotive, and 36 are return-tubular boilers, and there is 1 Redfield flue-boiler. The vertical tubular-boilers are used on 22 steamers, tonnage, 216.48; cubic feet (aggregate) of boilers, 1,450.65. The locomotive-boilers are used on 8 steamers, tonnage, 71.31; cubic feet of boilers, 225.86. The Redfield boiler is used on a boat of 16.68 tons, and has a volume of 135.19 cubic feet. The return-tubular boilers are used on 36 boats, tonnage, 565.31; cubic feet of boilers, 4,997.33. Hence we have cubic feet of boiler-volume per registered ton of steamer as follows:

	Cubic feet.
Return-tubular boilers	8.84
Redfield flue-boiler	8.10
Vertical tubular boilers	6.70
Locomotive-boilers	3.17

Average size of boats:

	Tons.
With return-tubular boilers	15.70
With vertical tubular boilers	9.84
With locomotive tubular boilers	8.91

Return-tubular boilers are the common type for tug-boats. There are no steel boilers in this class. All of these small boilers carry high pressures, that is, 60 to 100 pounds, but rarely over 100 pounds per square inch.

BOILERS OF NEW YORK STEAMERS.

CLASS I: Number of boilers enumerated, 162; rectangular and semi-rectangular, 14; cylindrical, 148; flue, 8; tubular, including flue and tubular, 154.

There are four vertical tubular boilers of a type already described. The steamer "Hudson," 1,872.68 tons, has four return-tubular boilers, each 9′ by 14′. The steamer "Louisiana," 2,840.33 tons, a new and swift steamer of the same line between New York and New Orleans, has eight cylindrical tubular boilers of a peculiar design patented by Mr. Baird. The "Clyde," plying between New York and Aspinwall, has two rectangular boilers 9′ high, 18′ front, 13′ long. The "Hudson City," 1,008.95 tons, has one drop-return flue-boiler 10′ in diameter by 33′ long. The "Central," 1,023 tons, has one return-flue boiler 10′ 3″ by 35′ long. The "Communipaw," 1,023 tons, has one return-flue boiler 10′ 6″ by 32′ long. The last three are well-known ferry-boats with beam-engines, The "Plainfield," "Fanwood," and other ferry-boats have similar boilers. The "Maryland," 1,093.03 tons, a transfer-boat plying between Jersey City and Harlem, has two semi-rectangular boilers 13′ 6″ wide and 16′ long. These are return-tubular boilers.

The rectangular type of boiler is much more heavy for the same boiler volume and strength than the cylindrical type. It requires a heavier shell and a greater weight of bracing, and is generally designed only for low pressures. It may be considered an old type and belonging to a period when boiler-pressures averaged much less than at present, as they now average less than they will probably average in the future. The idea in building rectangular boilers is an obvious one, viz, to fit the shape of the boiler to conform with the hold of the vessel. On this account some are now built especially to replace worn-out boilers of the same type.

The "Morro Castle," 1,713.61 tons, plying between New York and Charleston, has four return-tubular boilers, each 11′ 2″ in diameter and 10′ long. Each boiler has six hundred and eight 3″ tubes.

The "Saint John," 2,645.19 tons, plying between New York and Albany, has two flue-and-tubular boilers, each 13′ in diameter by 27′ 8″ long; tubes, three hundred and forty, 4½″; flues, twenty, of the diameters 16¼″, 17¼″, and 27½″.

The "Rio Grande," 2,556.29 tons, plying between New York and Galveston, has four return tubular boilers 11′ 8″ in diameter and 10′ long. Each boiler has three furnaces with 34″ flues and two hundred and six 3″ tubes.

The "Manhattan," 1,525.19 tons, plying between New York and Norfolk, has two lobster-back boilers, each 23½′ wide and 13½′ long. These are return-tubular boilers, and each has three furnaces. The aggregate grate area is 130′.

The "Hudson," of the New York and New Orleans (Cromwell) Line, with four return-tubular boilers, has 7,249.88 square feet of heating surface below the water-line to a boiler volume of 3,562.52 cubic feet; ratio about 2.03. The heating surface as estimated is distributed as follows:

	Feet.
Tubes	5,986.40
Furnace	521.24
Chambers	276.64
Back boxes	376 00
Front boxes	89.60

The grate surface is 180 square feet; ratio heating to grate, 33.25.

The "City of Augusta," 2,869.64 tons, plying between New York and Savannah, has six 12′ 6″ by 11 feet long return-tubular boilers of steel. The ferry-boat "New Jersey" has one 10′ 3″ by 33 feet long return drop-flue boiler of steel. The remaining boilers of this class are of iron. Of 162 boilers, there are 14 used singly, mainly ferry-boat boilers. There is 1 set of 8, and there are 4 sets of 6, 13 sets of 4, and 32 sets of 2 boilers.

CLASS II: Of 105 boilers, 62 are return-flue boilers, 2 sectional-tubular boilers, 2 direct-tubular, and the remainder return-tubular boilers. This is pre-eminently the ferry-boat class, and the drop-flue boiler is the prevailing pattern for ferry-boats.

The ferry-boat "Lackawanna," 891.89 tons, has one drop-return flue and tubular boiler 10′ 10″ in diameter and 24 feet long, with two furnaces. The ferry-boats "Princeton" (888.43 tons) and "New York" (881.01 tons) are peculiar in having direct-tubular boilers of steel. Each boat has one boiler 9′ 4″ in diameter and 33′ 6″ long. These are the only steel boilers in this class, but, like most ferry-boat boilers, carry low pressures. Much lower pressures are carried in the boilers of this than of the preceding class.

The "Benefactor," 843.55 tons, an ocean steamer in the coasting trade, is provided with two Babcock & Wilcox sectional tubular boilers. The high economy of water-tube boilers is generally admitted. The Montgomery water-tube boiler had vertical tubes in the direct, and the Martin water-tube boilers vertical tubes in the return, course of the products of combustion. The tube spaces were not easily accessible for cleaning, and the water was liable to "lift out" on account of defective circulation. In a Babcock & Wilcox boiler there is a series of inclined water-tubes fastened into end connections by expanding the tubes into accurate tapered holes. These end pieces connect with a horizontal steam and water drum located above the tubes, and the end piece at the back of the boiler connects the lowest point of the tubes with a mud-drum. The water-tubes are so placed that each horizontal row of tubes comes over the spaces in the previous row, and each tube is closed at each end by a hand-hole plate made steam-tight by accurately milling the joints. The tubes are thus accessible for cleaning, both within and without, and there is an active circulation, steam passing up the inclined tubes, and water flowing down from the steam-drum through the back connection. These boilers, as placed upon the "Benefactor," are cased in suitable supports for marine service. With the casing, they are 15 feet 6 inches in length and 11 feet 6 inches wide. There are 45 square feet of grate surface and 2,000 square feet of heating surface. The space occupied by this boiler is said to be about two-thirds that of the same capacity in fire-tube boilers.

The "Secaucus," 942.20 tons, has one drop return-tubular boiler 10′ 6″ by 24 feet. The "Rosedale," 938.65 tons, has two return flue boilers each 8 feet by 30 feet. The "Susquehanna," 921.28 tons, has one return-tubular boiler, 10 feet by 24 feet. The "City of Dallas," 914.55 tons, plying between New York and Jacksonville, Fla., has two rectangular return-tubular boilers, each 14½ feet wide, 11½ feet high, and 10½ feet long. To describe a rectangular boiler as wider than it is long might seem an abuse of terms, but the dimension of length is as usual taken in the direction of the tubes. The "Nassau," 504.37 tons, has one return-flue boiler 9 feet by 24 feet long. The "Minnie Cornell," 503.19 tons, has one return-tubular boiler 8′ 3″ by 29 feet long.

CLASS III: Of 169 boilers enumerated, about 66 per cent. are return-tubular boilers. There are 6 rectangular boilers. The "Amboy," a towing boat of 272.56 tons, has such a boiler 11′ 6″ wide, 10′ 6″ high, and 13′ 6″ long, of the return-tubular type. There are 3 locomotive tubular boilers. The "Annex No. 3" has such a boiler 7′ 2″ in diameter by 25′ 3″ long. There are twelve vertical tubular boilers which are employed mainly upon canal-boats. The largest is a boiler 78″ in diameter and 11 feet high upon the canal-boat "A. H. Smith," 126.23 tons. The canal-boat "City of Rochester," 126.23 tons, has one vertical tubular boiler 4 feet in diameter by 6′ 3″ high, with 162 2″ tubes. The freight-boat "Joseph Hall," 161.88 tons, has a Redfield flue-boiler, 4′ 6″ by 10′ 9″ (long). The inland passenger-steamer "Erastus Corning" has two return-flue boilers each 6′ 10″ by 26 feet long, and 33 other boats have flue boilers. The vertical boilers are characteristic of the canal-boats and the return-flue boilers of the ferry-boats, but the towing and inland passenger-boats have return-tubular boilers in the vast majority of cases.

Few boilers are of steel; not more than 4 or 5 out of 169.

The inland passenger-boat "Shadyside," 444.17 tons, has one return-flue boiler of steel. This is 7′ 9″ in diameter by 30′ long. The yacht "Polynia," 158.02 tons, has two 9′ by 10′ return-tubular boilers of steel. Each boiler has 210 2½″ tubes. The lighter "Transit" has one 7′ 6″ by 14′ return-tubular boiler, partly of steel.

Most of the elevator-boats have return-tubular boilers. The canal-boat "Steam Enterprise," 120.76 tons, has one 4′ 6″ by 19′ 2″ locomotive-boiler. The yachts "Corsair" and "Stranger," 247.40 tons, each have two tubular boilers, placed fore and aft, one on each side of the vessel. The boilers are 11′ in diameter and 10′ 6″ long, and each has two corrugated iron furnaces, 3′ 9″ in diameter, 148 3″ tubes, 42 square feet of grate, and 1,000 square feet of heating surface. The smoke-stack is 4′ in diameter and 24′ high. The ordinary boiler pressure is 90 pounds. The boiler volume in cubic feet nearly equals the heating surface in square feet.

The ferry-boat "Midland," 402.88 tons, has one drop return-flue boiler 8′ 6″ by 20′. This has 16 flues of different diameters, 11, 14, and 19 inches.

CLASS IV: Of 149 boilers enumerated, 4 are return-flue, 5 vertical tubular, and 149 return-tubular. One boiler is rectangular. The vertical boilers are upon yachts, fishing-boats, and small freight-boats. The inland passenger-boats "Only Son" and "Tiger Lily" have return-flue boilers. But the tug-boats, which make up the body of this class, have steam machinery of a uniform pattern, return-tubular boilers, and short-stroke, direct-acting, non-condensing engines.

The steel boilers in this class may be very briefly specified. The passenger-boat "C. R. Stone," 5,540 tons, has one return tubular steel boiler 7′ by 13′ long. The freight-boat "Clara," 73.65 tons, has one return-tubular steel boiler 5′ 6″ by 10″ long. The passenger-boat "Varuna" also has a return-tubular boiler of steel.

CLASS V: Of 145 boilers, 8 are vertical tubular, 5 Redfield, 2 locomotive, 1 vertical water-tube, and 129 return-tubular.

The inland passenger-boat "Rival," 45.51 tons, has an upright water-tube boiler. The inland passenger-boat "Governor Fenton," and the tugs "George H. Starbuck" and "S. E. Babcock," have Redfield boilers. There are four steel boilers upon the "Theresa," "Skylark," "Promise," and "Thomas Purcell," respectively.

CLASS VI: Of 106 boilers 39 are vertical tubular, 4 locomotive tubular, 1 water-tube, and the rest mainly return-tubular. There are 4 small rectangular boilers, beside the water-tube boiler, which is 6′ high on a 4′ square base. This is upon the yacht "Evil," 15.35 tons. The steam pressure allowed is 65 pounds. The yacht "Duplex" is returned as having 2 vertical tubular boilers of steel, each 3′ diameter by 4′ 2″ high. There are in all 8 small boilers of steel, most of them being upon yachts of less than 5 tons measurement.

EXAMPLES OF BOILERS FROM NEW YORK STEAMERS.

The statistics of the subject having been thus outlined, a more specific description of some of the more notable forms of boilers employed upon steamers plying from New York is here given. Return-tubular boilers are the common type for bay and ocean service, but the name covers considerable variety in detail.

What is commonly known as the marine type has a large shell, cylindrical or rectangular, containing one or more furnaces, and the grate bars extend over half the length of the boiler, the products of combustion passing into an uptake or rising box or flue at the back of the boiler and thence through return tubes over the furnace to the uptake proper or front uptake leading into the chimney. The uptakes are sometimes called front and back boxes. The return tubes are no longer than the furnace, but if they be extended in length, as we may often see that they must be from the stated length of a boiler, it is necessary to have flues to lead the products of combustion to the back uptake, and then we have the type of return-tubular boiler which may be fully described as the direct-flue and return-tubular boiler. Finally the boiler cylinder may be limited to the part inclosing the return tubes; and being properly supported, there may be a special iron or steel fire-box for the furnace or it may, with the bridge and back box, be built up entirely in fire-proof masonry. This is the land type of return-tubular boiler, but it is also employed upon steamers, especially upon river-boats. It is an arrangement which permits a small diameter of boiler and the employment of high pressures with safety. In case a water bottom is employed, as is quite usual, the direct flues or passages are inclosed within the cylindrical shell, as are also the furnaces when these are not accommodated by a separate rectangular front fire-box, which may also be surrounded by the water-space.

The usual form of return-tubular boiler with water bottom is illustrated in Fig. 21. In this boiler there are 68 square feet of grate to 2,215 square feet of heating surface. The scale of the drawing is $\frac{1}{4}''$ per foot.

The boilers of the steamer "Hudson" are of the return-tubular type and have 180 square feet of grate surface and 7,249.88 square feet of heating surface, divided as follows:

	Square feet.
Tubes	5,986.40
Furnace	521.24
Chambers	276.64
Back boxes	376.00
Front boxes	89.60

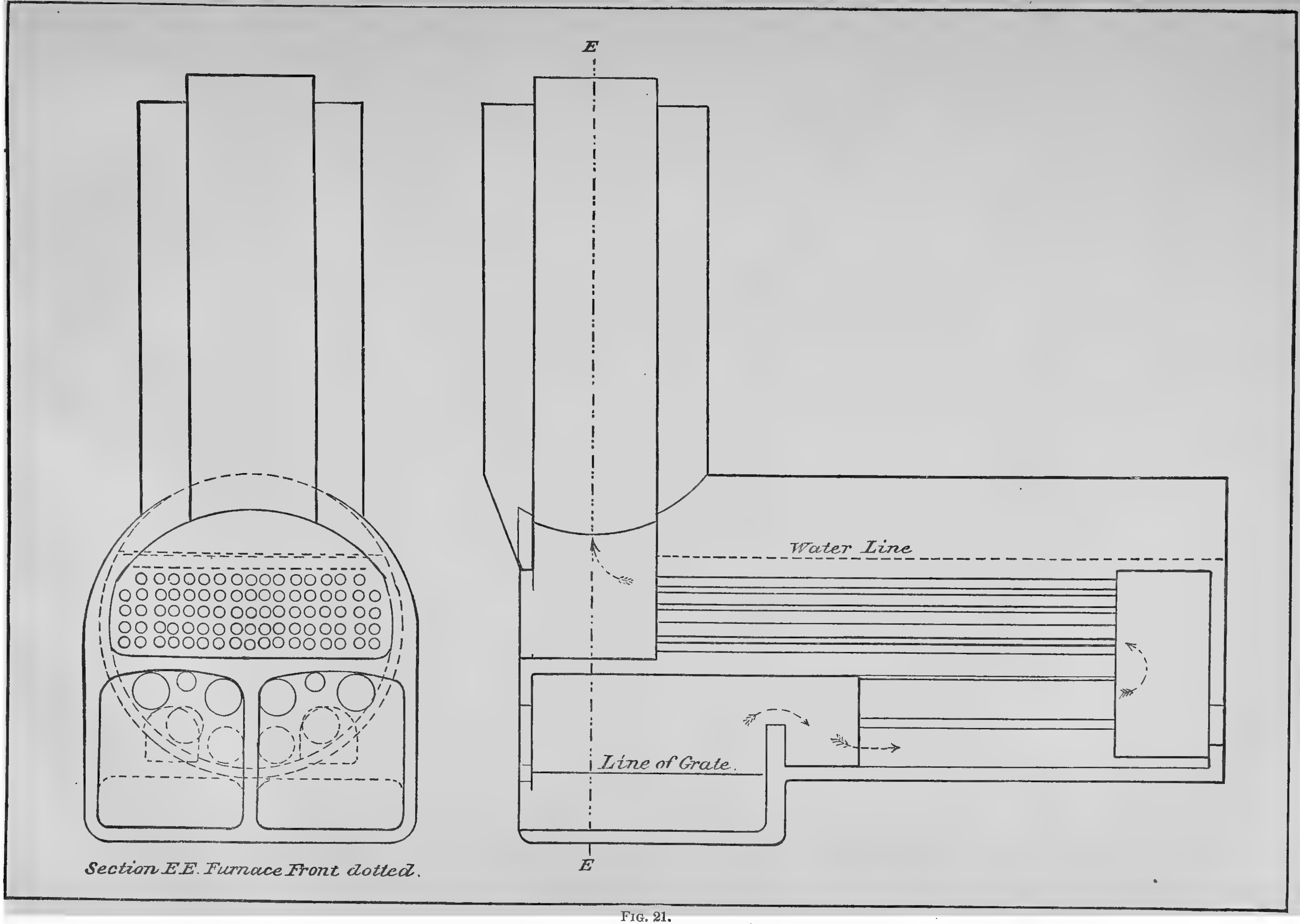


FIG. 21.

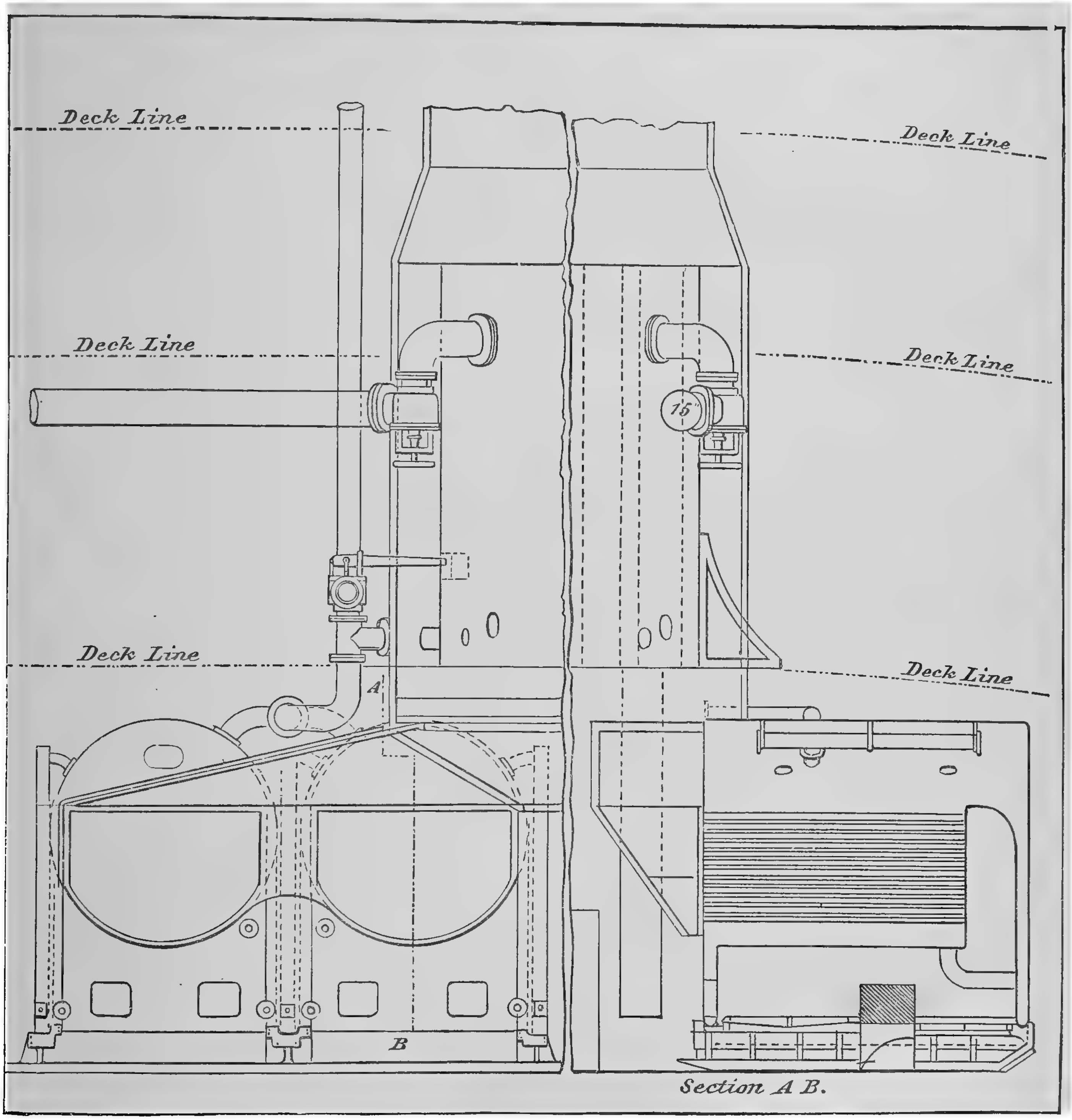

Deck Line
Deck Line
Deck Line
Deck Line
Deck Line
Deck Line
15"
A
B
Section A B.

Fig. 22.

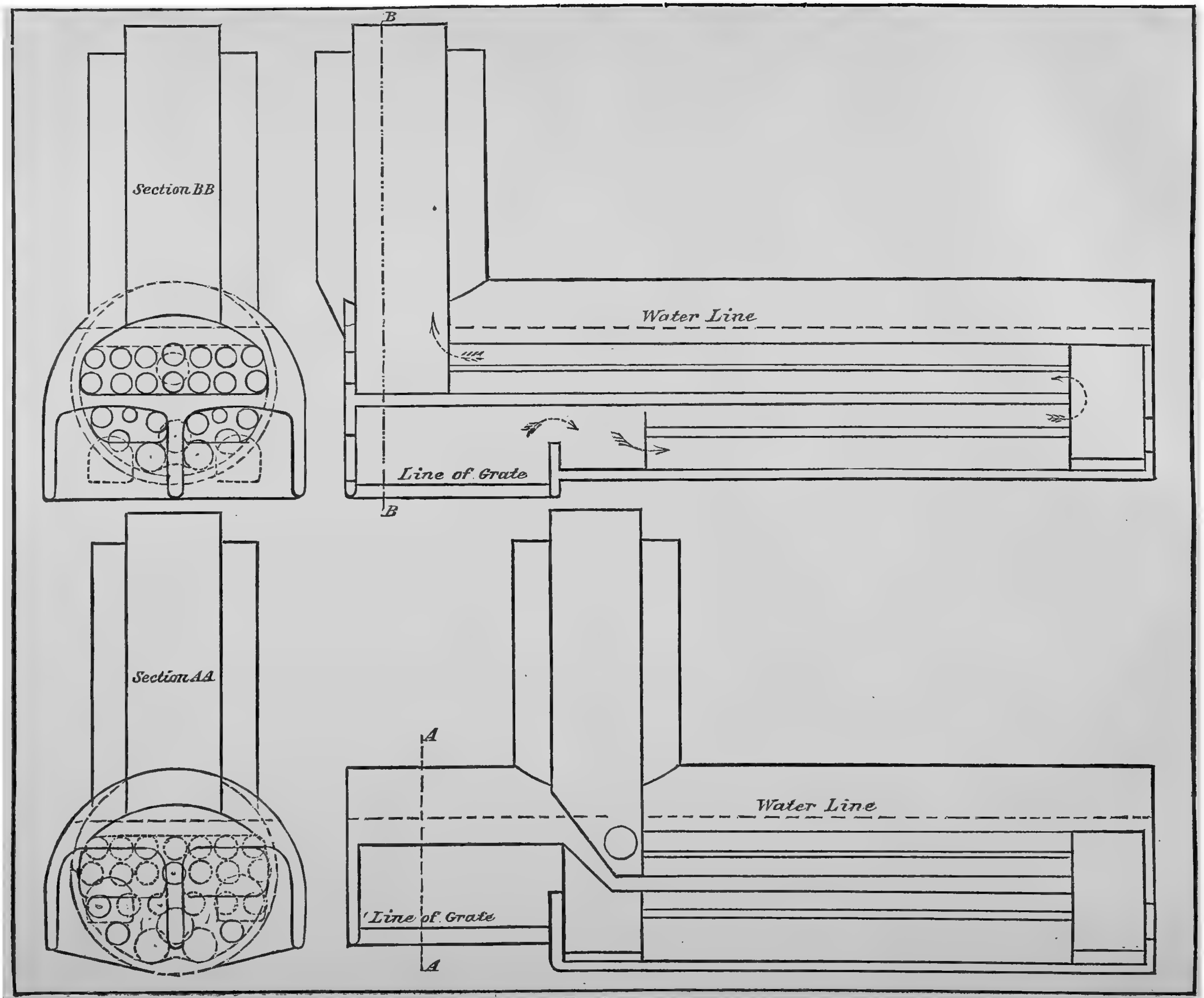

Section BB
Water Line
Line of Grate
B
B
Section AA
Water Line
Line of Grate
A
A

FIG. 23.

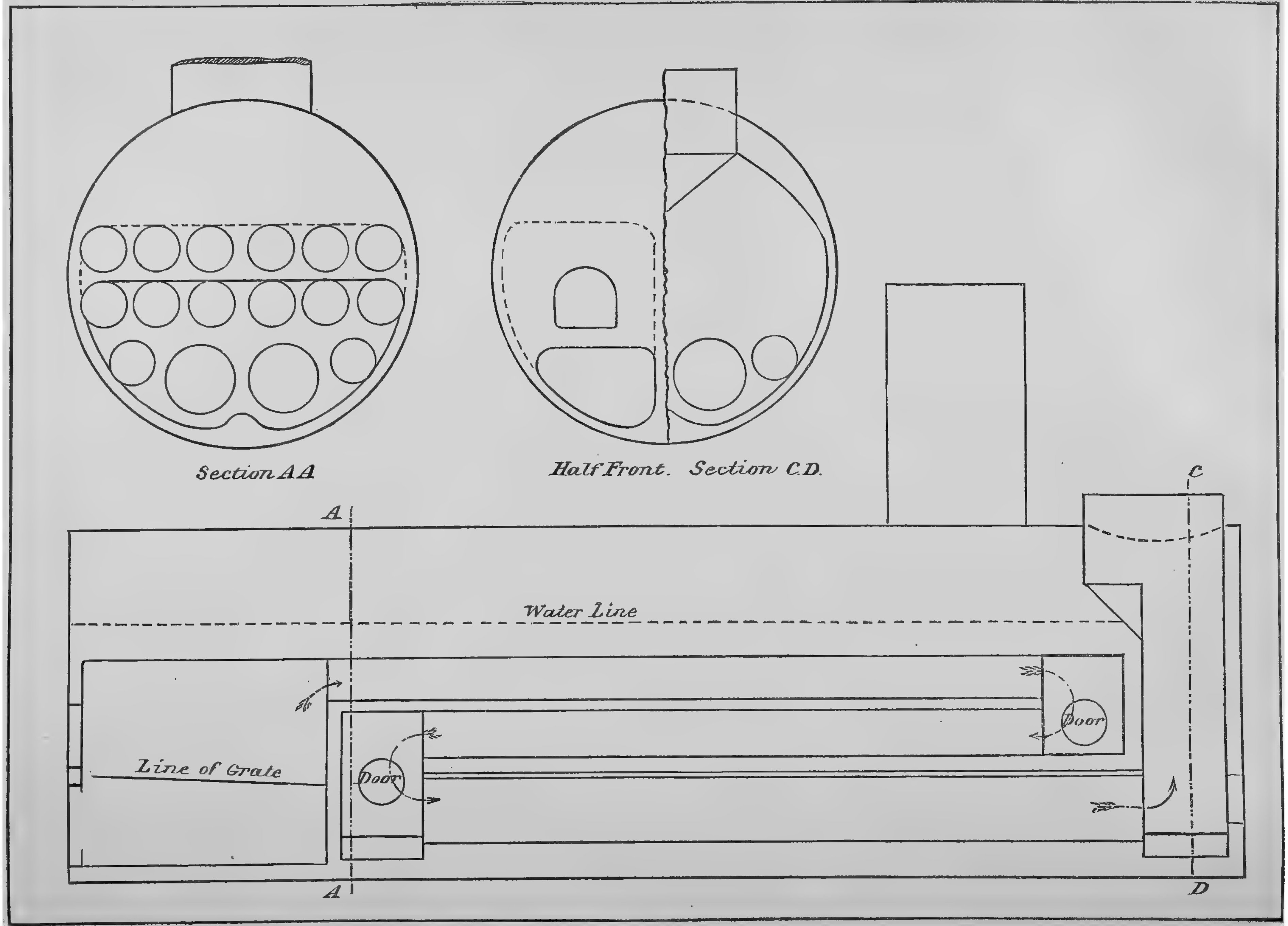

Section AA
Half Front. Section C.D.
C
A
Water Line
Line of Grate
Door
Door
A
D

FIG. 24.

This is below the water-line, superheating surface not being included. There are four boilers, 13′ 8″ long, 9′ 4½″ in diameter, the height of front or fire-box being 12′ 6″. Each has three furnaces 6′ long and one hundred and forty 3½″ diameter by 11′ 8″ long tubes. The following are the kinds and weights of material entering into the construction of these boilers:

	Pounds.
Plating	157,635
Cast iron	41,429
Forgings	58,959
Rivets	11,962
Sheet iron	1,620
Angle iron	1,481
Brass	399
Washers	400
Tubes	27,896
Total weight	301,780

The boilers of the steamer "Pilgrim" are of the Redfield type. There are 4 batteries of boilers, each with a set of 3 shells, each shell 7′ in diameter. The extreme outside width of boiler is 23′ 6″, length 15′. Each shell has one hundred and thirteen 3½″ by 12′ (long) tubes, and a furnace 7′ 6″ deep. The boilers are placed athwartship, and each battery has two 36″ by 12′ drums. They are connected by double breechings to two steam-chimneys or super-heaters 26′ high. The peculiarity of the Redfield type consists in the braced water-shell, which constitutes the framing. There is also a donkey boiler, of the locomotive type (used for pumping and other purposes), on board the "Pilgrim."

The "Mary Powell" has two steel boilers, each of the following dimensions: Length over all 26′, cylindrical shell 10′ diameter and 16′ 1″ long, fire-box 9′ long 11′ wide. There is a 5′ 10″ diameter steam-drum, and a 4′ 2″ diameter steam-chimney, the height of the steam-drum being 12′. The smoke-stacks are 4′ 6″ in diameter and 68′ high above the grate. There are two furnaces 4′ 10″ wide and 8′ long. There are ten direct flues 9′ 1″ long, two 14″, six 16″, and two 9″ in diameter, and the return-tubes are 4½″ in diameter. The grate surface for both boilers is 152 square feet; heating surface, 2,660 square feet; super-heating surface, 340 square feet; cross area of lower flues, 23 square feet; cross area of tubes, 17.2 square feet; chimney area, 25 square feet.

The "Louisiana" has eight boilers, having a total grate surface of 374 square feet and a total heating surface below water-line of 15,840 square feet. An illustration of a pair of these boilers is presented in Fig. 22. Each boiler has a length of 12′ 2″ and a diameter of shell of 8′ 6″, and there are 216 tubes in each. There is no water bottom extending under the furnace, but the cylindrical shell is supported by a detached water-jacket, the peculiar construction of which is exhibited in the drawing. The boilers are shown with steam super-heater, and smoke-stack connections in two views centering upon the smoke-stack. On the right hand side is a section looking forward, athwartship, and on the left hand is a fore and aft view showing half the smoke-stack and the set of two boilers on one side, there being in all four sets of two each. The deck lines are indicated, but to avoid confusion the ventilator pipes and some other ship details are not shown.

FLUE BOILERS.

The great number of flue-boilers employed in steamers running from New York and in the vicinity, in river, harbor, and coastwise service, calls for special mention of this class of boiler, which are principally of three types: the ordinary return-flue boiler, the lobster-back return-flue boiler, the drop return-flue boiler. The "lobster" pattern differs from the ordinary return-flue boiler mainly in having the furnace forward of the chimney. The drop return-flue boiler has three sets of flues, one extending from the upper part of furnace to a back box, and from this the products of combustion pass forward by a second and lower set of flues to a forward box or connection in which they drop a second time and traverse the length of the boiler by a still lower set of flues, finally passing out of the back uptake leading to the chimney. These important types of boilers, as built by Messrs. W. & A. Fletcher, are illustrated in Figs. 23 and 24. The ordinary return-flue boiler as shown has 72 square feet of grate to 2,000 square feet of heating surface. The lobster pattern return-flue boiler has 72 square feet of grate to 1,800 square feet of heating surface. The drop return-flue boiler has 64 square feet of grate to 2,015 square feet of heating surface. The flue-boilers of the lobster and ordinary types are shown without water bottoms under the furnaces, but they are often built with water bottoms.

BOILERS OF PHILADELPHIA STEAMERS.

In Class I all the boilers enumerated are return-tubular. The "Juniata," plying between Philadelphia and New Orleans; the "Norman," plying between Philadelphia and Boston; and the "Saxon," in general coasting service, have rectangular boilers. The "Juniata," 1,320.31 tons, has 2 boilers, each 10′ by 14′ 9″ (wide) by 10′ 6″ (long). The "Norman," 1,203.26 tons, has 2 boilers, each 9′ 10″ by 17′ 2″ by 9′ (long). The collier "Perkiomen," 1,035.35 tons, has 2 cylindrical return-tubular boilers 10′ 3″ by 8′ 8″ (long).

In Class II there are a considerable number of rectangular boilers, many of them upon vessels of recent build and some allowed no more than 20 pounds pressure. The boilers are almost invariably return-tubular, but the "Long Beach," 519.51 tons, has a 10′ by 28′ (long) drop-flue boiler. The city ice-boats have enormous boiler capacities, necessary to supply the power for breaking up ice on the Delaware Bay and River. No. 1, 325.97 tons (Class III), has four 8′ 6″ by 23′ boilers; No. 2, 458.02 tons, four 9′ 7″ by 22′ boilers; No. 3, 637.20 tons, eight 10′ by 12′ boilers, all being of the cylindrical return-tubular type. The collier "Berks," 553.09 tons, has one cylindrical return-tubular boiler, 8′ 8″ by 12′ (long).

In Class III the following four steamers have vertical tubular boilers.

The inland passenger-boat "Twilight," 466.93 tons, one rectangular vertical tubular boiler 11′ 6″ wide, 15′ high, allowed 35 pounds pressure.
The "Acadia," 387.26 tons, plying to the West Indies, two vertical tubular boilers, each 8′ diameter and 12′ 5″ high.
The yacht "Concord," 225.22 tons, one vertical tubular boiler 6′ 9″ diameter, 11′ 2″ high.
The inland passenger-boat "Cinderilla," 131.22 tons, one cylindrical vertical tubular boiler 5′ 1″ by 10′.

Most of the ferry-boats are in this class. They have cylindrical tubular boilers, 8′ diameter by 22′ long being an ordinary proportion. Most of the large canal-boats are also in this class. The canal-boats "Raritan," 166.83 tons, and "Delaware," 166.53 tons, have each a cylindrical return-flue boiler 7′ by 14′. The canal-boat "Fannie," 186.98 tons, has a 7′ 6″ by 13′ (long) return-tubular boiler. On the whole, while it may be said that there are relatively more rectangular boilers in the Philadelphia than in the New York district, there are relatively fewer flue-boilers in the former than in the latter district.

In Class IV, nearly all of the boilers are return-tubular, and the same holds true of the remaining classes with a larger number of vertical boilers as might be expected upon the smaller boats. The "Ibis, jr.," a small boat of 4 tons, has a Herreshoff coil boiler which is allowed 133 pounds pressure, and some of the small boats have locomotive-boilers.

But for a few exceptions upon boilers of steamers of the smallest class, it might be said that there were no steel boilers inspected in this district. There is, however, a 48″ by 42″ by 72″ high vertical tubular boiler of steel upon the boat "River Queen," 10.08 tons; a 5′ by 9′ cylindrical return-tubular boiler, partly of steel, on the yacht "Columbia," 19.87 tons; and a steel boiler, cylindrical vertical tubular, 3′ 10″ diameter and 5′ 6″ high upon the "Comet," a boat of 23.30 tons.

The frequent employment of large rectangular boilers in the Philadelphia district has been noted. The dimensions of such a boiler, one of a pair supplying steam to a 30″ and 50″ by 36″ compound engine are as follows: Length, 14′ 6″; breadth, 8′ 6″; height, 9′; type, compound direct-flue and return-tubular; flues, 4–11″ and 2–18″, all 5′ 6″ long; tubes, 64–4½″ diameter and 12′ long; heating surface, 1,241 square feet; grate-surface, 42 square feet; there being in each boiler 2 furnaces 6′ long and 3′ 6″ wide.

BOILERS OF BALTIMORE STEAMERS.

In Class I are sixteen boilers, all return-tubular, and one pair rectangular. The "Johns Hopkins," 1,470.97 tons, has two boilers, each 192″ in diameter and 13′ long. This steamer plies between Baltimore and Boston. The "Lancaster," 1,283 tons, a steamer plying from Philadelphia to points on the Atlantic coast, has two boilers, each 11′ diameter by 9′ 6″ long, with three hundred and seventy-two 3″ tubes.

In Class II are forty-seven boilers, the majority return-tubular. There are eight boilers of the Scotch type (flue and tubular), two of 10′ diameter by 12′ 6″ long on the "Saragossa," plying between Baltimore and Boston, and six of 9′ diameter by 11′ long on the "F. C. Latrobe," plying upon Chesapeake bay. The last are allowed 60 pounds pressure. Seven boilers are specified as flue-boilers and four are specified as rectangular boilers.

The "William Kennedy," 974.57 tons, plying between Baltimore and Providence, R. I., has one return-tubular boiler 12′ in diameter by 20′ long. This boiler has ten flues of several diameters, 16″, 14″, and 10½″, and one hundred and forty 4″ tubes 14′ 6″ long. The pressure allowed is 35 pounds.

In Class III, seven out of fifty-four are specified as return-flue boilers, and one as a rectangular boiler. Nearly all are return-tubular boilers. The river boat "Mary Washington" has two 3′ 6″ by 18′ tubular boilers; pressure allowed 80 pounds. In Class IV, nearly all of the boilers are of the usual return-tubular type, but the river boat "Virginia," 51.14 tons, has a 36″ by 12′ locomotive-boiler, and the river boat "William McKinney," 74.07 tons, has a 4′ 6″ by 10′ fire-box tubular-boiler. In Class V, there are specified 2 Scotch type, 3 vertical, and 1 locomotive boiler out of a total of 44, the rest being return-tubular boilers either with outside or inclosed furnaces. In Class VI there are 9 vertical tubular, 1 return-flue, and 39 return and direct tubular boilers.

Only four small steamers in this district have boilers of steel or partly of steel. The so-called Scotch-type boilers of the "Saragossa" are direct-flue and return-tubular, each having three 34″ direct furnace flues and one hundred and twenty-eight 3½″ return tubes. The tubes are 12′ long. The boilers are cylindrical in form, with an independent steam drum.

BOILERS OF NORFOLK, CHARLESTON, AND SAVANNAH STEAMERS.

In the Norfolk district, we find the same types of boilers as in the Baltimore district and in about the same numerical proportions. The "B. and J. Baker," 212.67 tons, plying between Norfolk and the West Indies, has one 7′ by 16′ flue and return-tubular boiler of steel and iron. This is the only steel boiler specified.

In the Charleston district, of 76 boilers enumerated, 16 are of the locomotive type. These are upon boats plying upon the Santee, Pedee, and Cape Fear rivers. The "Farmer," 470.01 tons, the "Merchant," 405.58 tons, and the "Planter," 384.35 tons, plying from Charleston to Cheraw and points on the Great Pedee and Santee rivers, have each two 54″ by 14′ tubular boilers of steel. These have shells $\frac{26}{100}''$ thick and are allowed a pressure of 120 pounds per square inch. The small steamers "Elizabeth" and "Oklahama" have vertical tubular boilers of steel.

In Class VI, of the Savannah district, five boats have coil-boilers of the Herreshoff type. The largest is the "Ogeechee," 8.39 tons, which has one 8″ by 12″ engine. The yacht "Josie," plying from Saint Augustine to Matanzas Inlet, has a coil-boiler with 100 feet of 1″ pipe and one $3\frac{1}{4}''$ by 6″ engine. The small yacht "Marie," with one $2\frac{1}{2}''$ by 3″ engine; the "Major Tilton," with one $3\frac{1}{2}''$ by 7″ engine; and the yacht "Olivia," with two 3″ by 5″ engines, have coil-boilers.

In Class VI, Charleston district, six out of fifteen boilers are vertical and five out of fifteen locomotive tubular boilers. In Class VI, Norfolk district, twelve out of thirty-five are vertical tubular. In Class VI, Savannah district, out of twenty-five boilers nine are vertical tubular, two locomotive, five coil, and the rest return-tubular.

The tug-boat "Arrow," 173.50 tons, plying upon Saint John's river, has one 54″ by 20′ locomotive-tubular boiler. The passenger-boat "Athlete," 178.85 tons, plying on Saint John's river, has one 8′ by 17′ 6″ return-tubular boiler. The "Florida," 475.71 tons, plying between Savannah and Palatka, has two 5′ by 19′ 10″ return-tubular boilers of steel. These have shells $\frac{26}{100}''$ thick and are allowed 120 pounds pressure. The small boats "Dart" and "Parole" have vertical tubular boilers of steel.

The "City of Macon," 2,092.80 tons, plying between Savannah and New York, has four 12′ 8″ by 10′ 6″ (long) cylindrical return-tubular boilers. These have shells $\frac{3}{4}''$ thick, of iron, and are allowed 80 pounds boiler-pressure. The "Gate City" and "City of Columbus," ocean steamers, plying between Savannah and New York, have each four 12′ 8″ diameter by 10′ 6″ long cylindrical return-tubular boilers, shells $\frac{92}{100}''$ thick; pressure allowed, 80 pounds. These are of iron. It may be remarked that the 12′ 6″ diameter steel boilers of the "City of Augusta" have a thickness of material of 0.762″ and are allowed 100 pounds pressure, and that the 14′ 6″ iron boilers of the "City of Alexandria" have a stated thickness of material of 1″ and are allowed 80 pounds pressure. Than the latter there are no thicker boiler-shells upon the coast.

BOILERS OF GULF STEAMERS.

Passing from the Atlantic to the gulf ports of the southern states, the influence of Mississippi river practice appears even as far as Key West, in the greater number of flue-boilers.

Of 25 boilers enumerated in the Apalachicola district, 8 are return-flue, 3 vertical, and the rest return-tubular. Plying upon the Apalachicola river we find the "Rebecca Everingham," a boat of 592.20 tons, with two 38″ by 16′ return-flue boilers of steel, and allowed the high pressure of 183 pounds per square inch. This is the only steel boiler specified. The ocean passenger- and most of the tug-boats have return-tubular boilers. The inland passenger-boats, many of which make short runs along the coast, have flue-boilers. The freight-boat "D. L. Yulee," 139.66 tons, has one 4′ by 22′ (long) return-flue boiler; pressure allowed, 108 pounds. For the same boiler capacity, the flue-boilers, being of small diameter, are commonly used in sets of two or more, while the tubular boilers are used singly.

When we reach the Mobile district the return-tubular boilers from being the rule have become the exception. The large propeller towing-boat "Lone Star," 482.10 tons, has one 10″ by 22′ 6″ (long) flue- and return-flue boiler. The John T. Moore, 457.31 tons, has four 38″ by 26′ (long) double return-flue boilers. Both of these boats are propellers. The "Bradish Johnson," an inland passenger-boat with paddle-wheel, has three 40″ by 28′ two-flue boilers. The paddle-wheel boat "Annie," 200.10 tons, has one direct-flue and return-tubular boiler, 7′ 10″ diameter by 20′ 8″ long. The tubes are 14′ 10″ long. The paddle-wheel tug-boat "Escambia," 94.98 tons, has two double return-flue boilers 3′ 6″ diameter and 20′ 6″ long. The boiler of the "Annie" is allowed 25 pounds; that of the "Escambia," 110 pounds pressure. There are in this district a considerable number of fire-box and locomotive tubular boilers, this being the usual type for towing-boats. The tug-boat "Coosawattie," 38.45 tons, plying on the Coosa river, has one 40″ diameter by 11′ 2″ long locomotive-boiler, which is allowed 100 pounds pressure. There are three or four vertical tubular boilers upon small yachts and tug-boats. The yacht "Lulu Burns," 3 tons, has a small steel boiler, and the passenger-boat "Maggie F. Burke," 284.37 tons, plying upon the rivers of Alabama, has two flue-boilers 42″ by 32′ of steel. The thickness of material is $\frac{26}{100}''$ and the pressure allowed is 173 pounds. The river freight-boat "Lillie Low," 64 tons, has two 3′ by 16′ flue-boilers of steel. The remaining boilers in the district are of iron.

Of the Galveston steamers, an enumeration made subsequent to the close of the census year by Mr. Lewis C. Hershberger, local inspector, gives the following data of boilers: Total number, 48; iron boilers, 45; steel, 3. The steel boilers are a return-tubular, 5′ 6″ by 11′ on the freight-boat "Daniel Peggotty;" a vertical tubular on the "E. D. Sidbury;" and an 8′ by 11′ return-tubular on the "Continental." There are 2 vertical tubular boilers, and of the horizontal boilers 15 are return-flue, 27 return- and 2 direct-tubular, and 2 flue- and return-tubular. The return-tubular boilers range in size from 2′ 4″ diameter and 3′ 6″ long to 8′ diameter and 16′ long. The return-flue boilers range in size from 3′ (diameter) by 12′ to 3′ 4″ by 24′. Sixteen boilers are used in sets of 2. Of these, 12 are return-flue boilers.

The steamers inspected at the port of New Orleans are divided, geographically, into two classes, the river-service and the gulf-service. The flue-boilers are mainly employed in the river-service. Steel boilers also are very common upon the river, but rare upon the gulf and harbor steamers. The "Enterprise," 1,041.20 tons, plying between New Orleans and Algiers, Louisiana, has four steel boilers of the return-flue type, each 4′ by 20′ (long).

The ferry-boat "Nathalie Hamilton," 148.99 tons, plying between New Orleans and Algiers, Louisiana, has one return-flue boiler 44″ by 26′ 6″ (long) of steel. The "Ella Andrews," 64.29 tons, plying between New Orleans and Pensacola, has one return-tubular boiler 7′ 6″ by 13′ of steel.

The "Chalmette," 2,982.96 tons, plying between New Orleans and New York, has four return-tubular boilers, each 13′ in diameter by 12′ 2″ long.

Of the steamers inspected at New Orleans, by far the greater proportion belong to the river-service. Of steamers of Class I, 14 out of 26; of Class II, 6 out of 15; of Class III, 3 out of 91; of Class IV, 6 out of 40; of Class V, 3 out of 30; and of Class VI, 2 out of 44 are specified as plying upon the Gulf; this not including boats specified as plying from New Orleans to the sea and the local service, nor the boats specified above as plying between New Orleans and Algiers. Of the thirty-four steamers specified the return-tubular is the characteristic type of boiler. The coasting-steamer "Chase," 576.47 tons, has one $9\frac{1}{2}$′ by 20′ fire-box return flue boiler. The "Heroine," 180.14 tons, classified as a lake, bay, and sound passenger-steamer, plies between New Orleans and Mobile, and has a haystack tubular-return boiler. This steamer was built at Glasgow, Scotland, 1862. Its boiler is 12′ in diameter and 13′ high, and has four furnaces and one hundred and fifty-two $2\frac{1}{2}$″ tubes to each furnace.

Among the boilers peculiar to stern-wheel steamers and propellers in the Mobile and New Orleans districts, there is little blending of type. We do not as a rule find the high-pressure flue boilers upon the propellers nor the lower-pressure tubular-boilers upon the stern-wheel boats. The style of boiler suited for a large light-draft boat is not suitable for a small harbor-tug; but high-pressure boilers of small diameter are used upon the propellers, while tubular boilers are the prevailing type for light-draft river-boats upon the Pacific seaboard. The preservation of the distinguishing types is due in no small degree to the fact that boats and boilers are for the most part built in two far-removed sections of the north, the Ohio river furnishing one type while the Atlantic seaboard of the middle states furnishes the other. If we have before us a list of New Orleans steamers with the places of build and the boiler-pressures allowed, either item will enable us to draw a probable inference as to the character, both of the boilers and engines, of any steamer in question. The following tables show how the boiler-pressures allowed range for the several districts and classes of vessels:

	New Orleans.		Mobile.		Galveston.		Apalachicola.	
	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.	Highest.	Lowest.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Class I	174	28	....	....	....	....	....	....
Class II	170	26*	....	....	....	25	183	....
Class III	181	30	173	25	135	50	150	30
Class IV	173	45	120	40	120	75	80	70
Class V	159	50	100	40	120	60	80	40
Class VI	115	50	130	55	100	65	80	60

For New Orleans the enumeration of steamers with boiler-pressures above and below 90 pounds is as follows, by classes:

	Number of steamers.	Boiler-pressures.	
		Above 90 pounds.	Below 90 pounds.
Class I	26	12	14
Class II	15	8	7
Class III	91	70	21
Class IV	40	30	10
Class V	30	17	13
Class VI	46	12	34

PROPORTIONS AND ARRANGEMENT OF STEAMERS.

Under this head I present some comparisons of the principal dimensions of steamers in various classes of service and built at various dates, so as to exhibit the peculiar requirements of different services and the tendencies of different periods. Accounts in some detail are also given of the constructive arrangements of a sufficient number of steamers in different classes of service to fairly illustrate the subject.

OCEAN STEAMERS.

Paddle-wheel steamers in ocean service are becoming the exception. They are less frequently used on the Atlantic than on the Pacific ocean, but a considerable number are inspected at the port of New Orleans, while in New England they are the prevailing type. The following examples may be cited:

Built before 1866.

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
Charleston	1859	1, 227. 03	233. 0	37. 2	23. 8
Clinton	1863	1, 187. 11	220. 0	34. 5	18. 2
Albermarle	1864	871. 43	172. 0	33. 5	19. 2
J. C. Harris	1865	994. 51	219. 9	33. 1	16. 6
Morgan	1865	994. 51	219. 9	33. 1	16. 6

Ratio length to breadth varies from 5.13 to 6.61; length to depth from 8.96 to 12.64.

Built since 1865.

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
Harlan	1866	1, 163. 02	219. 9	34. 1	16. 6
Josephine	1868	1, 282. 58	236. 8	24. 3	18. 0
Wyanoke	1870	2, 067. 62	208. 0	49. 5	21. 4
Whitney	1871	1, 337. 64	235. 5	35. 0	17. 1
Saint Johns	1878	1, 098. 84	250. 0	38. 0	12. 7

Ratio length to breadth varies from 4.20 to 9.74; length to depth from 9.72 to 19.68.

The later-built boats embrace a wider range of service.

Of screw steamers and steamships the following examples are cited:

Steamships built since 1874.

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
City of Atlanta	1875	1, 620. 95	242. 0	40. 0	20. 3
Niagara	1877	2, 265. 28	288. 0	36. 4	23 0
City of Rio de Janeiro	1878	3, 548. 30	345. 0	38. 6	28. 8
City of Para	1878	3, 532. 25	345. 0	38. 6	28. 5
Saratoga	1878	2, 426. 13	298. 0	38. 6	23. 5

Steamships built before 1875.

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
Geo. W. Clyde	1872	1, 804. 89	256. 0	35. 0	19. 2
Richmond	1872	1, 437. 96	206. 0	33. 0	21. 6
Pennsylvania	1873	3, 104. 28	343. 0	43. 0	32. 0
Colon	1873	2, 685. 75	292. 0	40. 0	20. 3
Carondelet	1873	1, 508. 29	248. 0	36. 0	21. 9

The ratio of length to breadth is 8.93 for the "City of Rio de Janeiro," 7.99 for the "Pennsylvania," 6.24 for the "Richmond," and 6.03 for the "City of Atlanta."

Screw steamers built before 1870.

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
Crescent City	1860	2, 003. 41	265. 4	34. 0	16. 6
Santiago de Cuba	1861	1, 679. 76	231. 0	38. 0	27. 5
Cortez	1863	1, 246. 18	209. 5	35. 3	17. 2
Saxon	1862	1, 293. 43	200. 0	34. 0	18. 6
Morro Castle	1864	1, 713. 61	255. 8	40. 0	23. 1

Screw steamships built since 1870.

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
City of New York	1873	1, 715. 73	242. 0	37. 0	19. 5
Hudson	1874	1, 872. 68	280. 0	34. 0	25. 8
City of Washington	1877	2, 618. 27	300. 5	38. 4	27. 5
Manhattan	1879	1, 525. 19	228. 0	35. 2	20. 2
City of Alexandria	1879	2, 480. 32	307. 0	38. 5	23. 7

The ratio of length to breadth is 5.88 for the "Saxon," 7.81 for the "Crescent City," 6.54 for the "City of New York," and 8.24 for the "Hudson." The general bluffness of build as compared with English practice is obvious, and the tendency toward greater relative lengths is slight.

EXAMPLES OF LARGE COASTING STEAMERS.

The "Decatur H. Miller," of the Merchants and Miners Transportation Company, is an iron steamer of 2,296.14 tons. It is 257 feet long on deck, 250 feet long on the 6 feet water-line from outside of stem to outside of main post, 38′ 6″ breadth of beam at the widest, 26 feet depth of hold, and 31½ feet depth over all. It is called a full three-deck vessel. The hold, 8′ 3″ deep, and above that the lower between-decks, 7′ 6″ high, are used for freight. Above these are the upper between-decks, 7′ 6″ high, and the promenade deck, upon which are houses coming above the body of the vessel. Upon the upper deck, apart from spaces for freight, hatches, stores, etc., there are three sections, the passenger saloon, 60 feet long aft, the machinery and steerage space, 70 feet long amidships, the forecastle, 46 feet long forward. On the promenade deck are two houses, one 70 feet long aft, containing the engine, mess, and officers' rooms, social hall and state-rooms for passengers, and one 40 feet long forward, containing the pilot-house and captain's and officers' rooms. The machinery space on the upper deck and in the upper between-decks contains not only the machinery but the kitchen, ice-house, and steerage. The machinery consists of four cylindrical tubular boilers, 11′ by 11′ and two 24″ and 54″ by 48″ compound engines with the high-pressure over the low-pressure cylinders. It occupies about 55 feet of the length of the vessel. Of the depth of hold, 26 feet, 23′ 3″ is clear space and 2′ 9″ decks, floors, and ceilings. On the upper deck, with the passenger saloon are 18 state-rooms, and in the forecastle are the quarters of sailors and firemen.

The iron framing of the vessel it is not within my present province to describe, but about the rudder and propeller it may be considered as the framing of the machinery, and the description of this is pertinent to our subject. The stern is of 8″ by 4½″ hammered iron, with a solid eye for the screw shaft, the eye being 10″ deep and 27″ in diameter. The rudder-post is 8″ by 4½″, bosses for rudder-pentles 8″ in diameter and 7″ deep, with lignum-vitæ bushing; opening for wheel, 5′ 3″ wide. The rudder-stock is 6½″ in diameter, extending above the upper deck and fitted with a quadrant and steering wheel. The rudder-frame is forged solid to the stock with two stiffening bars hanging on three pentles; heel pentle 4″ in diameter and 4½″ long, capped with brass; upper pentles 3½″ in diameter. The rudder is filled with white pine covered with ⅜″ wrought-iron plates. In the machinery section from the forward-boiler bulkhead to the aft-engine bulkhead the framing of the vessel is doubly heavy. Like most coasting steamers the "Decatur H. Miller" is designed for a mixed freight and passenger service, but the freight service is the more important feature. Land communication by rail is so much more rapid that the coasting steamers can only absorb a small proportion of the passenger traffic. This steamer is considered a swift vessel. It makes the trip from Boston to Norfolk in forty hours and fifty minutes, but a person can go from Boston to Baltimore by rail in less than one-fourth the time required by the boat under most favorable circumstances.

The screw steamer "Chalmette," one of the largest and most important steamers in the gulf trade, is of 2,982.96 tons register, length between stem and propeller-posts, 320′; over all, 340′; breadth of beam, 42′; depth from base line, 31′. Like the "Decatur H. Miller" the "Chalmette" has three decks, but with different arrangement and no provision for passengers. The sides of the vessel are iron to above the upper deck, which is flush, fore and aft. On this deck are the dining-room, kitchen, package-freight house, machinery hatch inclosure, captain's and officers' rooms, and pilot-house, the forecastle being below and forward on the main deck. In the completeness and excellence of her appointments for freight service the "Chalmette" merits especial mention. Steam power is called into play at every point where manual labor can be conveniently saved. An independent engine operates the windlass and forward capstan, which were made by the American Ship Windlass Company, of Providence. These windlasses are among the most commendable features of American marine machinery. There are also five separate freight-hoisting engines, which serve not only to handle the cargo but to work the aft capstan and handle the sails. There are three steam winches for handling sails and hauling. There are two large donkey-pumps for bilge and fire purposes, beside which there is a circulating-pump, also two 6″ Hancock inspirators and a boiler feed-pump. There is a steam steerer in the pilot-house forward, and for further security against accident there is a separate safety steering apparatus located in a house over the rudder-head. In all, there are fifteen engines on

board. The main engine is compound, 35″ and 70″ by 54″ stroke, of the steeple type. There are four 13′ by 12′ 2″ main boilers with a total of 12 furnaces, and there is one large donkey-boiler for furnishing steam for the numerous small engines. The screw propeller is 16′ in diameter and 22′ pitch.

The "Chalmette" has nine athwartship iron bulk-heads and three water-ballast compartments. A novel and effective apparatus is employed for signalling between engine-room and pilot-houses. The machinery for propulsion, including the boilers, occupies less than 60′ of length; but the labor-saving machinery is, as we have seen, distributed throughout the vessel.

The "Manhattan," of the Old Dominion Line, is a steamer of 1,525.19 tons, length 228 feet, breadth 35.2 feet, depth 20.2 feet. This steamer plies between New York and Richmond and is largely engaged in the fruit and vegetable trade. Besides accommodations for officers and crew, it has provision for 40 cabin and 30 steerage passengers. There are four water-tight bulkheads, and bulkheads around the boilers and machinery. There is one 28″ and 53″ by 4 feet compound engine with steam reversing gear, steam syphon and independent circulating-pump, and there are two lobster-back boilers, each 10′ 5″ in diameter and 22′ long. These have 130′ of grate-surface, there being three furnaces in each boiler. Of auxilliary machinery, there is a platform elevator for cargo in the forward hold and improved hoisting machines and windlasses. There are three anchors, of 3,000, 1,500, and 800 pounds, respectively. The propeller is 13′ in diameter and 20′ 6″ in pitch. The hub is of cast iron with steel blades.

The "City of Augusta," of the Ocean Steamship Company, is more particularly a passenger-steamer, and one of the finest upon the coast. It is 302 feet long, 42.2 feet broad, and 17 feet deep, with a registered tonnage of 2,869.64 tons. It is a three-deck vessel, with main deck, spar-deck, and hurricane-deck, the last the whole length and width of the ship, with a pilot-house and officers' rooms upon it forward and a long saloon aft, the lower decks being occupied by dining-halls, parlors, state-rooms, forecastle quarters for seamen and firemen, steerage quarters with 30 berths, an ice-house of 15 tons capacity, butcher shops, lockers, store-rooms, and the like. The principal machinery space begins at the middle of the vessel and extends some 60 feet forward. The machinery has already been described.

SIDE-WHEEL STEAMERS.

In the arrangement of side-wheel steamers the most characteristic feature consists in the guards, which are extensions of the main deck fore and aft of the wheel batteries to the full width of the steamer over all. The effect of this is to greatly increase the available space upon the main deck, and, as the guards are tapered off fore and aft, the plan of the main deck has a tendency toward the lozenge shape. This and the utility of the increased space

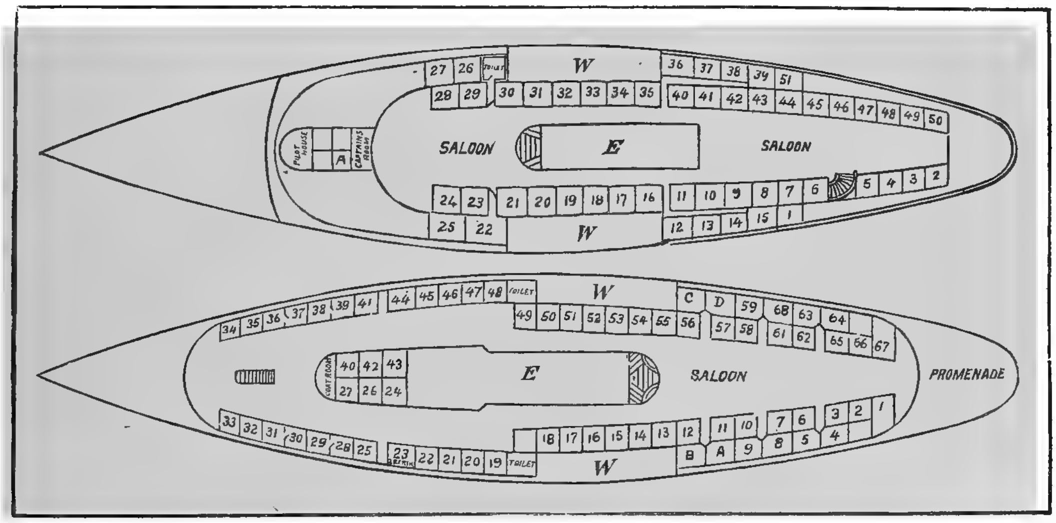


FIG. 25.

is well illustrated by the deck plans of two New England steamers, shown in Fig. 25. The engine and boiler spaces are shown by the letters E and the wheel spaces by the letters W, and we see at a glance how large a proportion of the state-rooms are accommodated upon the guards. The guards are supported by cross timbers, called sponsons, projecting from the hull of the vessel, and in some cases these extensions are carried so far that the width of deck is nearly double the breadth of beam. Sometimes the boilers are placed upon these guards.

The following dimensions of the "Mary Powell" are given by Theron Skeel: Length over all, 294′; on water-line, 286′; beam over all, 64′; on water-line, 34′ 3″. The mean draft is 6′; depth of hold, 9′; height from main deck to promenade deck, 10′; promenade deck to upper deck, 8′. The displacement is 28,000 cubic feet; midship section, 200 square feet; projected area of head-wind surface, 2,000 square feet. The crew of the "Mary Powell" comprises fifteen men, captain, clerk, baggage-master, two pilots, two engineers, four firemen, and four deck-hands.

The usual arrangement of sound and river boats is with engines and boilers upon the main deck, where most of the state-rooms are located. The hold accommodates the freight, and contains the quarters of deck-hands and others, the kitchen, and often a dining hall or ladies' saloon. The main deck is taken up by saloons and state-rooms, and the promenade deck by parlors, promenades, and state-rooms. The pilot-house is upon the top or hurricane deck, which is little utilized. A new plan of building river steamers is to put the machinery in the hold. This gives more room upon the main and promenade decks, and by imparting greater steadiness to the boat permits the use of the hurricane deck as a promenade. The new sound steamer "Pilgrim" has her machinery in the hold. The "Pilgrim" is 400′ long over all, 50′ beam, 88½′ over guards, 17½′ depth of hold, 11′ draft, having three decks and accommodations for three hundred passengers. The strength of the hull is much greater than usual. There is practically a double hull braced upon the longitudinal bracket plate system. The space between the so-called hulls is 24″ at the sides and 36″ at the keel. It is divided into a great number of water-tight compartments by the longitudinals and floor brackets, added to which there are six athwartship water-tight bulk-heads of $\frac{6}{16}$″, $\frac{5}{16}$″, and $\frac{7}{16}$″ plate. The machinery, boilers, smoke-pipes, kitchen, and wheels are inclosed in iron as a precaution against fire.

FERRY-BOATS.

In the ferry-boat the space in the hold is of little value, single deck room being the all-important consideration. This has, in some cases, led to the employment of inclined engines, which occupy the hold and leave more deck room; but the beam-engine ferry-boat still remains the more usual type. These differ considerably in their principal proportions, as may be seen by comparing the Jersey City ferry-boat "Erie," 981 tons, with the Hoboken ferry-boat "Lackawanna," 891.89 tons.

Name.	Length.	Breadth.	Depth.
	Feet.	*Feet.*	*Feet.*
Erie	136. 5	40. 0	14. 1
Lackawanna	195. 8	35. 8	12. 8

The Brooklyn ferry-boats and those plying between Boston and East Boston have inclined engines. The "Montana," 734.25 tons (Brooklyn), and the "Revere," 550.94 tons (East Boston), have the following dimensions:

Name.	Length.	Breadth.	Depth.
	Feet.	*Feet.*	*Feet.*
Revere	150	33. 4	12. 2
Montana	172	35. 8	12. 5

In all these cases, while the ratios of length to breadth vary considerably, there is great uniformity in the ratios of breadth to depth, these ranging from 2.74 to 2.86.

The "Lackawanna" is a new boat. It is 62′ wide over the guards, and has wheels 19′ in diameter and 8½′ across the face. The beam-engine has a bore of 44″ and a 10′ stroke. The drop-return flue-boiler, elsewhere described, is the type principally used on ferry-boats. That upon the "Lackawanna" is 24′ long and 11′ feet in diameter, and has two furnaces. The draft of the boat is about 7½′. This boat is of iron and is considered the strongest ferry-boat afloat. It has two water-tight bulk-heads and is specially strengthened at the ends to resist the shock of ice.

TRANSFER BOAT.

The "Excelsior," 774.43 tons, of the Potomac Steamboat Company, is a railroad transfer-boat, with passenger accommodations. There is on the main deck a single track capable of accommodating a train of four cars. There are two inclined engines 40″ by 10′ cylinders with a jet-condenser, and the main deck is left clear for cars, all the machinery being in the hold. The "Excelsior" is 232′ long, 37′ broad, 10.5′ deep. There is a large passenger. saloon on the promenade deck, and there are a number of state-rooms on the guards. The water-wheels are "composite," with two lengths of arms, and are of oak and iron. The wheels are 28′ in diameter and 8′ face. In place of the usual hog frames, the "Excelsior" has a double row of Howe truss framing. Besides a 44″ (diameter) by 7′ donkey boiler, there are two through-arch and return-tubular boilers each 10¼′ in diameter and 29′ long, and with 75 square feet of grate- and 2,250 square feet of heating-surface.

SOUND STEAMERS.

The following examples are cited of large side-wheel steamers plying upon Long Island sound:

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
			Feet.	Feet.	Feet.
City of Boston	1861	1,591.90	301.0	40.0	12.3
Old Colony	1865	1,957.55	310.0	42.0	14.0
Bristol	1867	2,962.20	362.0	48.0	16.6
City of Lawrence	1867	1,678.06	243.0	62.5	11.0
State of New York	1866	1,417.03	286.0	36.0	9.6
C. H. Northam	1873	1,436.86	312.0	44.0	10.0
Rhode Island	1873	2,742.42	325.0	45.6	15.4
Massachusetts	1877	2,606.83	323.8	42.5	15.9

For these, except the "City of Lawrence," the average of length to breadth is 7.55, and to depth 23.66.

RIVER STEAMERS.

Of Hudson river passenger-steamers, the following examples are cited:

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
			Feet.	Feet.	Feet.
Metamora	1846	304.27	168.0	25.0	8.0
Armenia	1847	528.29	212.0	30.0	9.0
Eagle	1852	422.69	166.0	26.0	7.6
Daniel Drew	1860	930.35	260.0	30.0	10.0
Mary Powell	1861	983.57	288.7	34.4	9.0
Thomas Cornell	1863	1,160.85	286.6	38.8	10.0
Chauncey Vibbard	1864	1,066.98	281.0	35.0	9.6
Albany	....	1,346.53	284.0	40.0	10.1

Of these steamers, the average ratio of length to breadth is 7.51; length to depth, 26.55. The examples of side-wheel steamers in the coasting trade, previously cited, give average ratios of length to breadth 6.21 and length to depth 11.28 for the steamers built before 1866, and the ratios 6.35 and 13.40, respectively, for those built since 1865. The river steamers average about five-sixths as broad and half as deep as the ocean steamers for the same length. The Hudson river is so deep and easily navigable that it is sometimes spoken of as being more like an arm of the sea than a river, and the steamers plying upon it, although smaller than those of the principal lines through Long Island sound, are relatively (not actually) deeper.

The following examples are cited of large towing-boats upon the Hudson River. These are side-wheel boats, and some of them, as will be seen, nearly half a century old, the oldest steamers in service in the United States:

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
			Feet.	Feet.	Feet.
Belle	1835	433.87	220.0	27.0	9.6
Norwich	1836	255.68	160.0	25.0	8.6
Niagara	1846	510.54	251.0	30.0	9.0
C. Vanderbilt	1847	680.81	300.0	36.0	9.0
Connecticut	1848	723.79	303.0	36.0	8.0
America	1852	407.19	212.0	30.0	9.0
Austin	1853	380.56	197.0	31.3	8.3
Geo. A. Hoyt	1872	298.21	165.2	30.5	9.4

Of these boats, the average ratio of length to breadth is 7.36; length to depth, 25.50. The "Connecticut" is relatively broader and shallower than the "Belle," and the "Geo. A. Hoyt" is relatively broader and deeper than the "Connecticut."

Of the proportions of river steamers, the following examples are cited from other sections:

Locality.	How employed.	Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
					Feet.	*Feet.*	*Feet.*
Delaware river	Towing	Camden	1844	151.25	126.0	19.2	8.8
Do	...do	Bristol	1871	152.65	115.3	22.3	8.3
Do	...do	Col. Thomas A. Scott	1875	154.53	130.1	21.0	8.0
Do	Passenger	Nellie White	1866	444.30	172.0	38.0	8.0
Do	...do	Thomas Clyde	1878	625.73	212.0	31.0	7.0
Do	...do	Republic	1878	1,285.02	272.4	37.0	10.8
Do	...do	Clio *	1878	117.19	94.0	22.0	6.0
Potomac river	...do	Mary Washington	1859	297.70	135.0	28.0	5.5
Do	...do	Mattano	1859	278.60	143.50	22.0	6.8
Do	...do	Mystic	1866	194.56	116.65	21.3	6.6
Do	...do	W. W. Corcoran	1878	441.31	147.3	27.8	7.9
James river	...do	Ariel	1858	493.82	180.9	29.0	18.8
Do	...do	N. P. Banks	1863	333.99	159.6	26.6	8.8
Do	...do	Accomack	1877	434.57	136.8	25.5	8.3
Altamaha and Savannah rivers	...do	Carrie	1867	212.90	133.9	27.1	6.5
Do	...do	Katie	1867	190.03	130.0	25.2	5.2
Do	...do	Clyde	1870	211.89	102.4	29.2	4.2
Do	...do	Centennial	1875	150.87	120.6	31.3	6.2

* A screw propeller.

Of the smaller boats, propellers and small tugs, the proportions are relatively deep and wide, the ratio of length to breadth generally ranging between 3½ and 5, and of length to depth between 10 and 20.

FREIGHT-BOATS.

Of New York freight-boats, the following examples of proportionment are cited:

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
			Feet.	*Feet.*	*Feet.*
John Stevens	1845	1,380.41	237.6	30.7	10.4
Marina	1849	144.96	85.0	20.0	7.0
Colden	1851	781.21	186.0	32.0	11.0
Ellen	1853	94.15	93.0	17.6	7.0
Lone Star *	1875	2,255.39	281.0	38.1	27.2
Edward Clark	1876	206.80	109.6	23.5	8.4
Flora	1878	99.83	91.6	24.0	6.6
Pioneer	1865	329.85	137.0	23.2	7.5

* Ocean freight steamship.
All of these, except the "Colden," are screw propellers.

The Reading colliers of Philadelphia have the following proportions:

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
			Feet.	*Feet.*	*Feet.*
Rattlesnake	1868	417.44	170.0	29.6	12.4
Centipede	1869	436.88	169.0	29.6	11.5
Achilles	1870	763.51	196.6	37.0	13.2
Hercules	1870	764.33	200.4	37.0	13.5
Panther	1870	699.10	190.5	36.0	13.3
Perkiomen	1874	1,035.35	219.0	36.8	17.2
Berks	1874	553.09	189.0	29.0	14.4
Reading	1874	1,283.00	248.4	37.1	18.3

As five others of this last type were built in 1874, it may be considered as the conclusive result of experience in ocean freight steamers for the coal trade. The ratios of length to breadth have been gradually increased in the above series without much change in the relative depth. The ratios are as follows:

Name.	Year.	Length to breadth.	Length to depth.
		Feet.	*Feet.*
Rattlesnake	1868	5.74	13.71
Centipede	1869	5.71	14.70
Achilles	1870	5.31	14.89
Hercules	1870	5.42	14.84
Panther	1870	5.29	14.32
Perkiomen	1874	5.90	12.73
Berks	1874	6.58	13.12
Reading, and others	1874	6.69	13.57

STEAM PILOT-BOATS.

The first steam pilot-boat, the "Jennie Wilson," 77.58 tons, was built in 1878, at Camden, New Jersey, for the New Orleans service. It is 78.5′ long, 18′ broad, 8.9′ deep. It has one 15″ and 26″ by 20″ (stroke) compound engine and a cylindrical tubular boiler, 8′ and 8′ 10″ in diameter and 12′ long, allowed 85 pounds pressure. The second steam pilot-boat was improvised from the Philadelphia sea-going tug "Hercules" for the New York and Sandy Hook Pilot Association. The third steam pilot-boat was built by the Harlan & Hollingsworth Company for the Board of Maryland Pilots. The dimensions of this boat are 113′ between main posts, 122.6′ long over all, 23′ beam, 12.9′ depth. It has a quarter-deck 3′ 3″ above the main deck for about 68′, commencing about 20′ from the stern. Upon this deck are the pilot-house and captain's room, and here are carried two boarding-yawls, each 17′ long. Under the quarter-deck is a main cabin, with sleeping berths, engineer's room, kitchen, and store-rooms, and the forecastle contains chain-lockers, bunk-room, and store-rooms. There are three anchors, 800, 500, and 175 pounds in weight; 60 fathoms of $\frac{3}{4}$″ and 60 fathoms of $\frac{7}{8}$″ cable, and a pump-brake windlass. There are two 1,000-gallon water-tanks, and the boat is heated throughout by steam. The power is furnished by one inverted direct-acting compound engine, 22″ and 36″ by 26″ (stroke), with tubular surface-condenser, and air, feed, bilge, and circulating pumps. There is a separate reversing engine for shifting the main valve-links. There is one cylindrical return-tubular boiler, carrying 70 pounds of steam, and an independent steam-pump for boiler-feeding, washing decks, and fire and other service. The boat is of iron, and there are two close iron bulkheads, one forward of the boilers. Coal-bunkers on each side of the boiler, from the boiler bulkhead to the fire-room, accommodate 40 tons of coal, and there is additional storage-room for 40 tons more. It is said that steam-boats of this character will soon supersede the sailing pilot-boats at our principal ports. These facts in regard to steam pilot-boats are derived mainly from the columns of the Nautical Gazette.

CANAL-BOATS.

The following are examples of New York canal-boats, giving some idea of the size of the Erie canal:

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
			Feet.	*Feet.*	*Feet.*
Wm. Wells	1859	130.31	96.0	17.6	9.8
City of Detroit	1875	122.00	97.0	17.8	9.0
City of Rochester	1874	126.23	96.5	17.5	9.4
A. H. Smith	1866	1[illegible]8.40	95.3	17.6	8.9
City of Troy	1874	124.16	95.5	17.5	9.4

The following are examples of canal-boats of the Philadelphia district:

Name.	Year.	Tonnage.	Length.	Breadth.	Depth.
			Feet.	*Feet.*	*Feet.*
Annie	1861	288.63	139.6	22.2	8.4
Anthracite	1862	226.32	121.7	24.8	6.8
Ann Eliza	1855	233.82	111.7	22.4	7.9
Black Diamond	1862	211.25	119.0	22.6	7.1
Novelty	1850	204.31	99.5	24.5	8.1
Vesper	1871	331.25	146.6	22.1	8.1
Triplet	1874	338.79	152.8	23.0	8.0
Sarah Fleming	1873	70.97	95.5	22.0	5.5
Richmond	1862	44.19	73.0	15.0	6.2

These proportions call for little remark. Breadth and depth are limited by the size of the canal, and length is limited by the size of locks. All of these boats are propellers.

YACHTS.

Of the arrangement of machinery upon small yachts and tug-boats there is not very much to be said. The boilers, of whatever type, are usually placed forward of the engines, which occupy little space. The advantages of condensation are often obtained by a simple arrangement which is illustrated in Fig. 17, page 45. The sketch shows the after part of a boat. A pipe passes from the exhaust of the engine through the side planking of the boat, where it is elbowed in a shoe or sabot and continues back around the stern post and forward upon the other side of the boat which it enters through the elbow of another sabot and connects with the air-pump. The tube is sometimes tapered down continuously from the engine to the air-pump, but good results are obtained by diminishing the diameter of the tube at the stern elbows. Thus from a 3″ exhaust-pipe leads a 3″ condenser-tube of hard drawn brass. At the stern a reducing elbow changes the tube to a 2″ diameter.

On the large yachts "Corsair" and "Stranger" there are two cylindrical boilers set fore and aft—that is, with length parallel with the length of the vessel. The fire-room is between the boilers, and coal bunkers, with a capacity of 40 tons, are located forward at the back of the boilers. The coal consumption of these yachts is about 10 tons a day.

In yachts, tugs, and the smaller steamers of whatever kind, the boilers, if horizontal, are set fore and aft. They are so set in some large ocean steamers, and necessarily so in the river steamers and ferry-boats with long flue-boilers. Short return-tubular boilers of large diameter (such as employed on many ocean steamers) and short rectangular boilers are set athwartship, and the fire-room is in the middle of the ship between the boilers.

SPEED OF STEAMERS AND GOVERNMENT OF ENGINES.

The very interesting subject of the speed of steamers is one which cannot be treated with exactitude for the following reasons:

Tests of speed are not made with a scientific observance of the conditions. On long runs distances are often roughly approximated, and the help or hinderance of winds and currents is not accurately considered. Ships under sail have been driven long distances at the rate of over 17 miles an hour, and with the power of steam added to that of a favoring wind much higher speed can be made than without the wind. As there are no claims of speed over 25 or 26 miles an hour under any circumstances, it is reasonable to suppose that the highest simple steaming speed is several miles an hour less for any considerable distance.

It has been noted as a curious fact in one of our engineering journals (*Mechanics*) that speeds made over the measured mile can seldom be made at that rate for a full hour. The conclusion has usually been jumped at that what was true for one minute would hold equally true for sixty, but this does not seem justifiable. Boats which can steam for three or four minutes at the rate of 15 miles an hour are found to have made no more than 11 miles at the conclusion of a full hour, and boats which can steam for a few minutes at 20 miles an hour fail to make more than 15 miles in a full hour.

Of swift steamers, the engine of a large paddle-wheel boat will make only about 60 or 70 revolutions in going a mile, the engine of a large screw-steamer will make 150 or 200, and of a small yacht 600 or 700. If the boiler-pressure and admission be maintained, while the speed made for 1 or 2 miles is not maintained, we have only to look to the inefficiency of the propelling-wheels for an explanation of the phenomenon. As a rule, marine-engines do not carry governors. Silver's, Fairbairn's, and other forms of marine governors have been applied to prevent the racing of propeller-wheels when the water-pressure upon the wheel is variable, as it may be in stormy seas, but the speed of the steamer is the ordinary governor of the engine. It is a matter which calls for practical experiment, but it may be remarked that slight variations in the speed of engines appear to cause serious variations in the efficiency of action of the propelling-wheels, that the periodicity of such variations appears to extend over a considerable number of revolutions, and that the steadiness of the engines appears to be maintained by variations in equilibrium between the effective and non-effective portions of the effort of the propelling-wheel.

Knots (sometimes called nautical miles) and miles are often confused in reports of speed. The knot is 1.1508 miles, or a little over a mile and a seventh long. In the following notes of speeds reported some may have to be taken with allowances. Not all are given as examples of high speed, but some of ordinary speeds with steamers of the classes specified.

The well known report of Mr. Theron Skeel upon the performance of the "Mary Powell" gives the following data: Wheels, 31′ total diameter; buckets, 10′ 6″ long by 1′ 6″ wide, 26 to a wheel; immersion of buckets (maximum) at mean draft, 3′ 6″; revolutions, 12,000 to 13,000 in 90 miles at a speed of 19 *to 20 miles an hour*, with a slip from 11.9 to 14.5 per cent. Revolutions per minute, 21 or 22. Initial pressure, 40 pounds; cut-off, 0.47; vacuum of condenser, 25″; pressure at end of stroke, 16.4 pounds; mean back pressure, 5.6 pounds; indicated horse-power, 1,540. The "Mary Powell" has run from Poughkeepsie to Vesey street, New York, in 3 hours and

33 minutes, exclusive of 6 landings, and is stated to have run from Milton to Poughkeepsie in 9 minutes. The steamer "Albany" has made a straight run from Poughkeepsie to the Twenty-fourth street landing, New York, in 3 hours and 13 minutes, and from Cozzen's Landing to West Point in 2½ minutes. From Poughkeepsie to Twenty-fourth street is 74½ miles. The "Albany" in her fast run carried 47 pounds steam and the engine made 26½ revolutions per minute. The "Carolina," a steamer of Chesapeake bay, makes a regular run of 60 miles in 3 hours 49 minutes. The "Sun," one of the early Hudson river steamers ran from New York to Albany in 12 hours. The "North American," built in 1827 for Hudson river service, made 17 miles an hour. The sound steamer "Rhode Island" makes 18 or 19 miles an hour, and averages 16 miles an hour over a 160-mile route. Her wheels are 37½′ in diameter and 12′ broad, and at her best speed she makes only about 17 revolutions. The speed of the "Albany," about 24 miles an hour, is stated never to have been exceeded for a long run except by the "Idaho," in a run to Japan. The English "Yarrow" yachts and torpedo boats have made 23 or 24 miles an hour. The "Ho-nam," a large Chinese river boat with compound beam-engine, of English build, went over the measured mile at a rate of about 16 miles an hour.

Turning now to ocean steamers, we find that the "Ohio," of the American line, makes an average speed of 14¾ miles an hour, at which rate the slip is 6.8 per cent. This steamship has run nearly 400 miles at about 15⅕ miles an hour. In 1856 the United States steamer "Wampanoag" made 407 knots in 24 hours with the wind forward and no sail. This is equal to 19.51 miles an hour, and has scarcely been exceeded; never, under the same conditions. The English steamer "Stirling Castle" is stated to have made the measured mile at a rate of 21.3 miles an hour, but its speed for long runs would probably be several miles an hour less. The first Cunarder, "Brittania," crossed the ocean in 1840 at a rate of 8.5 miles an hour. By 1852 the rate was only 9.11 miles an hour. It has since been doubled for swift runs of the best transatlantic steamers. One of the best runs of the "Alaska," of the Guion line, was 419 miles in 24 hours (Benjamin). The "City of Rome" went over the measured mile at a rate of 18.01 miles an hour. The speed of the "Assyrian Monarch" is 14.57 miles an hour.

The performances of the large American coasting steamers show some of the highest speeds yet attained in long-route ocean service. The "City of Washington" ran from Havana to New York in 75 hours 21 minutes, the fastest time from Havana, and stated to be the "fastest time by an ocean steamship for 75 consecutive hours." The speed was 19.27 miles an hour. July 4, 1875, the steamer "Hudson" left New Orleans and made the quickest time on record to New York, viz, 5 days 9 hours. July, 1880, the record was lowered by the steamer "Louisiana," as follows:

July 7,	8.30 a. m.	Sailed from New Orleans.
7,	3.20 p. m.	Crossed the bar.
8,	noon.	381 miles from New Orleans.
8,	11.15 p. m.	Off Tortugas.
9,	noon.	330 miles additional.
10,	noon.	413 miles additional.
11,	noon.	364 miles additional.
12,	4 a. m.	228 miles, Sandy Hook abeam.
12,	5.10 a. m.	20 miles, New York.

Allowing 1 hour 4 minutes for difference in time, this is 15 knots an hour, the distance being 1,736 miles; time, 4 days, 19 hours, 36 minutes. The "Louisiana" has since lowered this record by several hours, and has made long runs at the rate of 17¼ knots, or over 19¾ miles, an hour. The "City of Pekin" has made 15.8 knots or 18.18 miles an hour. The "Decatur H. Miller" runs from Boston to Norfolk in 40 hours 52 minutes, a rate of about 17 miles an hour. The coal consumption of these steamers is at least fairly economical.

Upon smooth water and with adequate boiler and engine power, small steamers can be made to make as fast time as large ones. A number of torpedo boats and small steam yachts have made over 20 miles an hour, but these are usually the records of short runs, and their maintenance of the speed even for a single hour is not always beyond question. At sea, small boats cannot compete with large steamers in speed. The smallest steamers that have crossed the Atlantic, such as the "Game Cock" and the "Anthracite", have made only 7 or 8 miles an hour. The little tug "Mea" ran from Philadelphia to Galveston in 180 hours (7½ days) at the rate of nearly 12 miles an hour, and with an economical consumption of fuel.

It is fairly presumable that with steadily-governed marine engines more steady speed could be made, and high speed could be better maintained. Marine governors of the Westinghouse type are employed by Messrs. William Cramp & Sons, not to act upon the throttle-valve, but by the throw of a lever to admit steam behind a piston, and cause the link to shift its position. This attachment is made to the steam-cylinder of the reversing-gear, by which an engine may be completely reversed in five seconds. Governors are sometimes connected with the stop-valve, but this connection does not serve well with compound-engines, because there remains steam enough in the receiver between the engines, together with the vacuum in the condenser, to prevent the throttling from being immediately felt. To prevent racing, the steamer "City of Atlanta", of the Charleston line, has a Fairbairn governor. The operation of this is very simple. A leaden ball weighing over 1,000 pounds is hung in a joint of the main shaft forward of the engine, and is free to swing in any direction. When the steamer rolls there is no trouble from racing, because the propeller is not thrown out of the water; but when the steamer

pitches fore and aft there is liability to trouble from racing, because the propeller is thrown up. The weight swings sidewise without affecting anything, but as soon as the boat pitches, it begins to swing fore and aft, and by a train of mechanism partly closes a regulator-valve between the stop-valve and the cylinder, thus closing up the engine until the propeller and the boat pitch back to their normal positions, when the weight falls back also and releases the valve. The "City of Atlanta" has a 4′ diameter by 5′ stroke simple condensing-engine.

CARRYING CAPACITY OF STEAMERS.

PASSENGERS: Upon ocean steamers the number of passengers of all grades per ton of vessel does not exceed 40. The "City of Pekin", per 100 tons register, has accommodations for 36 steerage and 3 cabin passengers. Large ocean steamers used as troop ships accommodate less than 40 soldiers per hundred tons of vessel. For long voyages the necessary carriage of coal and supplies is great. A large ocean steamer often employs one-third or more of its freight capacity in carrying coal for power.

Inland steamers and excursion boats, which make short runs and carry but a small weight of supplies, have a maximum carrying capacity of 2 persons per ton. The ratios of maximum numbers of passengers allowed per ton of vessel are as follows for the specified steamers plying in and about New York:

Plymouth Rock	1.66	Twilight	1.88	Bay Ridge	1.66	Jesse Hoyt	1.15
Grand Republic	2.16	T. V. Arrowsmith	1.89	Adelphi	1.55	Harlem	1.22
Tiger Lily	2.70	Sylvan Dell	1.70	St. Johns	1.05	Chrystenah	1.05
Thos. Collyer	2.33	Rosedale	1.92	Shadyside	1.35	Chancellor	1.36
Seth Low	2.05	Pleasant Valley	1.99	Sylvan Grove	1.41	Wm. Fletcher	0.96
Norwalk	2.10	Minnie Cornell	1.59	Riverdale	1.39	Sylvan Glen	0.76
Long Branch	2.29	J. B. Schuyler	2.01	Richard Stockton	1.43	Sea Bird	0.43
John Sylvester	2.52	Idlewild	1.98	Osseo	1.22	Mary Powell	0.51
Eliza Hancox	2.14	Gen. Sedgwick	1.71	Morrisania	1.43	J. H. Starin	0.57
D. R. Martin	2.30	Fort Lee	1.53	Josephine	1.17	Black Bird	0.60
Americus	2.02						

In some cases there is a passenger to as little as 3¼ square feet of single deck area with the maximum number on board, but as there are usually several decks, the space per passenger would be somewhat greater.

COAL.

The collier "Pottsville" carries 1.29 tons coal per registered ton of vessel. The "Berks" carries 1.08 tons per ton of vessel. The fleet of Reading colliers has carried 3,290,283 tons coal since 1869 (to end of 1879), running 3,017,853 miles—that is they have averaged nearly a mile run to every ton carried. A diagram (Fig. 26) exhibits more forcibly than words or figures the work of one of these colliers. Coal weighs per cubic foot about 50 pounds heaped, 75 or 80 pounds solid. The large square of the diagram represents approximately the area of 4 foot deep solid coal seam necessary to be mined to supply this collier with cargo for 5½ years' service. A smaller square exhibits the amount of coal carried in a year and a still smaller one the amount carried per voyage. The plan of the collier is also sketched to the same scale.

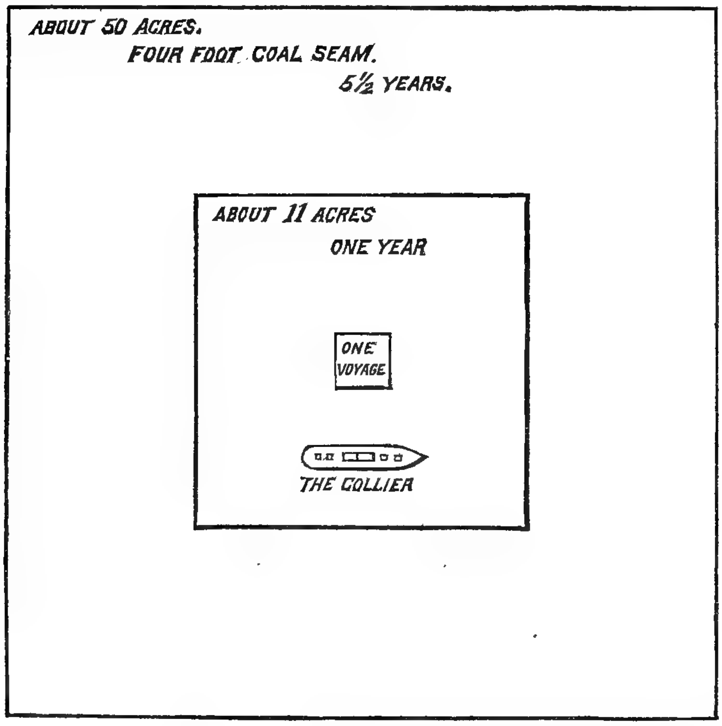


FIG. 26.

GENERAL FREIGHT.

The large coasting-steamers carry 2 or 3 bales of cotton per ton of vessel. The "Louisiana" carries 3.17 bales per ton, her cargo being 9,000 bales. Two hundred gallons of molasses in hogsheads are carried per ton of steamer in some cases, and upwards of 7 barrels of rice, oranges, and other products, and upwards of 18 or 20 bags of coffee. Molasses has been carried in the bulk, in which way the capacity may be increased. The necessity for carrying so much coal always takes a great slice out of the cargo space. The whaler "Mary and Helen" had storage space for 6½ barrels of oil per ton of vessel, in addition to which she carried nearly half a ton of coal per ton of vessel, without which her oil-carrying capacity would be fairly doubled. The great ferry-boat "Solano" carries about half its registered tonnage in weight of freight-cars.

STEAMERS OF THE PACIFIC COAST DISTRICT.

GEOGRAPHICAL DISTRIBUTION.—The employment or service of steamers may in some cases be definitely stated within geographical limits, but in many cases, especially in the river and coasting trade, there is no practicable method of classification which can indicate exactly the ranges and routes of service, simply because there is no uniformity of route. Nevertheless, as a basis for further considerations of the subject, and as a general index of the distribution of the steam tonnage, tables have been formulated assigning the steamers to various bays, rivers, and ocean routes, as far as their service could be defined from the obtainable data. Of this classification of the steamers of the Pacific coast, it may be said that the small craft specified as in the coasting trade are boats similar to those employed in bay and sometimes in river service, often with non-condensing engines, and making short runs along the coast. The larger vessels enumerated under the caption "Pacific Ocean and Coasting" comprise the ocean steamships plying from San Francisco to China, Panama, British Columbia, Oregon, and Southern California. Many of the steamers specified as plying upon the Sacramento and San Joaquin rivers ply also upon San Francisco and San Pablo bays.

	STEAMERS OF 1,000 TONS AND OVER.				STEAMERS OF 500 TO 1,000 TONS.				STEAMERS OF 100 TO 500 TONS.			
	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.
Pacific ocean and coasting	17	39,052.24	19	3,544.34	7	5,250.06	10	236.17	17	4,284.33	25	184.54
San Francisco and San Pablo bays	8	13,937.85	10	1,783.35	6	4,896.65	7	752.33	16	3,301.82	25	258.07
Humboldt bay									1	104.07	2	3.45
Puget sound and adjacent waters									15	3,651.52	23	401.17
Sacramento and San Joaquin rivers									28	7,007.44	53	425.71
Columbia and Willamette rivers	2	2,358.84	4	136.74	19	12,205.49	38	361.56	27	7,709.36	54	252.33
Coquille river												
Umpqua river									1	101.02	2	2.65
Colorado river									4	829.46	8	55.32
Lake Tahoe												

	STEAMERS OF 50 TO 100 TONS.				STEAMERS OF 25 TO 50 TONS.				STEAMERS OF LESS THAN 25 TONS.			
	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.	No. of steamers.	Tonnage.	No. of engines.	Cylinder capacity.
Pacific ocean and coasting	6	499.87	8	25.63	3	130.01	4	3.66	3	56.15	4	0.74
San Francisco and San Pablo bays	4	308.53	6	31.28	9	360.05	11	25.16	6	38.97	8	1.06
Humboldt bay	2	174.63	4	19.33	4	167.76	7	8.52				
Puget sound and adjacent waters	11	893.25	18	47.13	5	187.19	6	2.52	7	91.29	8	1.55
Sacramento and San Joaquin rivers	15	1,161.94	29	65.74	5	192.95	7	9.99	15	143.64	16	6.40
Columbia and Willamette rivers	8	701.71	14	20.43	11	418.73	17	7.46	11	108.44	14	1.95
Coquille river	1	85.56	2	2.65					1	16.81	1	0.23
Umpqua river									2	16.54	3	0.29
Colorado river												
Lake Tahoe	1	68.14	2	6.29	1	28.00	1	0.79	2	35.00	3	1.54

ENGINES.—Of engines in steamers of over 1,000 tons, 12 are used in pairs, 21 singly; 15 are compound, 12 simple condensing, and 6 simple non-condensing. The length of stroke is less than the diameter of cylinder in 2 engines, once to one and a half (inclusive) times as great in 8 engines; once and a half to twice (inclusive) as great in 6 engines; twice to thrice (inclusive) as great in 10 engines; and over three times as great in 7 engines, the smaller cylinder only being considered in compound engines. The two very short-stroke engines were built in the early part of the past decade. These are compound engines in ocean service. In compound engines the relative diameters of large and small cylinders are chiefly shown in the following sizes:

Large.	Small.	Ratio of cross-section areas.
Inches.	*Inches.*	
80	50	2.96
73	42	3.02
60	36	2.78
56	30	3.46
44	24	3.36
40	21	3.79

The strokes range from a length equal to the diameter of the larger to a length less than the diameter of the smaller cylinder.

In only one beam condensing-engine does the stroke exceed three times the diameter. This engine is a new one, a similar engine of the same stroke and nearly twice the diameter being built a dozen years ago, and carrying half the pressure. Upon averaging a considerable number of beam condensing-engines upon boats of over 500 tons, we find the ratio of length of stroke to diameter of cylinder to be, for boats built in the periods—

Period.	Ratio.
1865–1870	2.34
1870–1875	2.41
1875–1880	2.55

The respective average pressures being 33,41 and 50 pounds. For a single boat built twenty-five years ago, the stated ratio is 2.03 and the pressure allowed only 20 pounds. In such cases the limitation of pressure is due to the engines not less than to the boilers, the machinery as designed for low pressures being too light to permit any great increase of pressure.

There is thus indicated the usual tendency toward higher pressures and higher piston speed. The rotative speed is limited by the resistance of large non-feathering paddle-wheels, a beam-engine with 12′ stroke and 480′ piston speed having about 20 revolutions a minute. With this type of engine and wheels the progress of pressure and rotative speed stops at about 50 pounds pressure and a small number of revolutions, while with direct-acting marine-engines for ocean service screw-propulsion, and with the non-condensing engines and small wheels of light-draft river boats, both the speeds and pressures have continued to increase. Engines for screw-propellers use from half as great again to double the pressures employed in beam-engines, with from three to seven times the rotative speed, and while the river-boat engines driving paddle-wheels cannot have so great a rotative speed, the pressures allowed are much higher, the range being about as follows:

	Pounds.
With simple direct-acting non-condensing engines	90 to 150
With compound direct-acting condensing engines	60 to 90
With simple condensing beam-engines	20 to 60

It will thus be seen, taking into consideration both pressure and speed, that the value of cylinder capacity in the production of power may for the same volume and ratio of expansion be over five times as great in the first as in the last type of engines. As a matter of fact, where the ocean steamships have 11 tons of vessel per cubic foot of cylinder the large boats of the Columbia river have 17 and the large ferry-boats of San Francisco bay 8 tons burden per cubic foot of cylinder. For the next class of steamers (from 500 to 1,000 tons) there is still greater discrepancy in the ratios, the average number of tons burden per cubic foot of cylinder being for the ocean and coasting steamers about 22, for the ferry- and towing-boats of San Francisco and San Pablo bays about 6½, and for the boats of the Columbia and Willamette rivers about 33, the larger ratios being partly due to the slow freight as compared with the passenger service, while the towing-boats have relatively large engine powers.

Of the engines of steamers of between 500 and 1,000 tons, 46 are used in pairs, 9 singly; 6 are compound, 9 simple condensing, and 40 simple non-condensing. The length of stroke is from once to twice (inclusive) the diameter of the cylinder in 12 engines, twice to three times (inclusive) in 10 engines, three to four times (inclusive) in 13 engines, and over four times in 20 engines.

With the exception of two pairs of compound engines on ocean steamers, all of the paired engines of this class are upon the boats of the Columbia and the Willamette rivers, and with but one exception all of the long-stroke engines (ratio stroke to diameter between 3 and 5) are paired engines upon these river boats. In this class all of the condensing-engines are upon boats running in or from San Francisco bay, except one pair of engines on a boat running between Portland and Sitka.

The river boats comprise a series of examples with a great degree of similarity in relative length, breadth, and draft, and in character of service. Most of them were built in Oregon within the past five years, and in them if anywhere would we expect to find uniformity in the proportions of steam machinery. A small number of patterns would probably serve to equip such a fleet of steamers in a manner which would enable them to do their work as well and as economically as with a separate design of cylinder for nearly every boat. As it is there are in this class only six pairs of engines having like dimensions of cylinder, three 17″ by 6′ in boats from 165′ long, 37′ broad, 5½′ deep, 710.13 tons, to 154′ long, 36′ broad, 5.3′ deep, 555.99 tons, and three 16″ by 6′ in boats from 157′ long, 36′ broad, 5′ deep, 502.35 tons, to 154.4′ long, 35.8′ broad, 5′ deep, 586.98 tons; while the others present an assortment of individual patterns. Six boats, with tonnages ranging between 600 and 700 tons, have an average cylinder capacity of 14.4 cubic feet each, while seven smaller boats, with tonnages ranging between 500 and 600 tons, have an average cylinder capacity of 19.5 cubic feet each, all of the engines being of similar types and using high pressures, the average boiler-pressure allowed being for the six boats 121 pounds, and the average for the seven 118 pounds, per square inch.

Of the condensing-engines in this class there are six beam-engines of five sizes (two having 50″ by 11′ cylinders), three simple direct-acting engines, and four sizes of compound engines.

Of engines in steamers of from 100 to 500 tons, 160 are used in pairs and 28 singly, and one vessel in the Willamette district is driven by a 4 cylinder engine. Nineteen out of 192 are compound engines, 25 are simple-

condensing, and 148 simple non-condensing engines. The length of stroke is less than or equal to the diameter of cylinder in 9 engines, once to one and a half times (inclusive) the diameter in 17 engines, once and a half to twice (inclusive) in 20 engines, twice to three times in 20 engines, three to four times in 86 engines, four to five times in 38 engines, and over five times in 2 engines (a pair upon the "Satellite").

In the Willamette district there are in this class only 3 condensing-engines, 2 being compound. All of the remaining compound engines are in the San Francisco district, and of the remaining 24 simple condensing-engines 17 are in the San Francisco and 7 in the Puget sound district. In the entire first or Pacific district, on account of a few large ocean steamers, nearly two-thirds of the steam tonnage is driven by condensing-engines, but the river boats are driven almost exclusively, and the bay and harbor boats very largely, by non-condensing engines.

The 4 boats on the Colorado river (San Francisco district) have the following dimensions and engines:

Length.	Breadth.	Depth.	Tonnage.	Engines.	
				No.	Dimensions.
149.8	38	3.6	236.47	2	16″ x 5′
147.5	28	3.8	231.37	2	16″ x 5′
150.0	32	4.0	183.03	2	16″ x 6′
127.0	26	4.0	178.59	2	14″ x 5′

These are very light-draft boats for the tonnage.

Of the simple engines in steamers of from 100 to 500 tons there are four 22″ by 8′ cylinders, four 20″ by 6′, six 18″ by 6′, eight 16″ by 6′, ten 16″ by 5′, eight 16″ by 4′, four 15″ by 5′, twelve 14″ by 5′, four 14″ by 4½′, twelve 14″ by 4′, sixteen 12″ by 4′, eight 12″ by 3′, four 10″ by 4′, four 10″ by 3′, eight 10″ by 1⅓′, and four 9″ by 3′ cylinders, 57 sizes of cylinder remaining, of which there is a single engine or a pair of each.

Of engines in steamers of from 50 to 100 tons the following enumeration is made:

	In pairs.	Singly.	Compound.	Simple condensing.	Simple non-condensing.
San Francisco district	38.0	4.0	1.0	6.0	35.0
Willamette district	16.0	5.0	1.0	4.0	16.0
Puget sound district	16.0	4.0	0.0	4.0	16.0

Of the cylinder proportions, ratios length of stroke to diameter of cylinder:

District.	1 or less.	1 to 1½.	1½ to 2.	2 to 3.	3 to 4.	Over 4.
San Francisco	8	3	3	6	22	....
Willamette	2	4	2	4	7	2
Puget sound	....	3	....	1	11	5
Total	10	10	5	11	40	7

One boat in the Willamette district is driven by two engines of different sizes, and in the Puget sound district there are several small engines of unusually long stroke. Among the non-condensing engines in the San Francisco district there is a noticeable number of vertical direct-acting engines of short stroke, but the horizontal long-stroke direct-acting engines, working in pairs, are the more usual type.

Of engines in steamers of from 25 to 50 tons, 30 out of 53 are used in pairs; 49 out of 53 are simple non-condensing, 1 being simple condensing and 3 compound. Ratio of stroke to diameter is 1 or less in 15 engines, 1 to 1½ in 17, 1½ to 2 in 8, 2 to 3 in 6, 3 to 4 in 4, and over 4 in 3 engines. The long-stroke horizontal or slightly-inclined engines have in this class given place to the short-stroke vertical engines used in screw propulsion. With ratios of stroke to diameter of under and over 2 we have, respectively:

Steamers.	Ratio.	
	Under 2.	Over 2.
50 to 100 tons	25 engines	58 engines.
25 to 50 tons	40 engines	13 engines.

The steamers of from 50 to 100 tons are mainly freight and inland passenger-boats, and those from 25 to 50 tons are mainly tug-boats. Despite this fact the ratio of cylinder capacity to tonnage continues to diminish, the cylinder capacity being, per hundred tons, 5.61 cubic feet for vessels of 50 to 100, and 3.91 cubic feet for vessels of 25 to 50 tons.

The "Silva," a boat of 50 tons, plying from Eureka to landings on Humboldt bay, is driven by two 8″ by 12″ oscillating engines.

All steamers under 25 tons are driven by simple non-condensing engines. Of 58 engines, 22 are used in pairs, 36 singly. The "Jane West," plying between Astoria and Portland and the Cascades, a boat of 13.44 tons, is driven by one 8″ by 24″ engine. Of all the steamers under 25 tons in the Pacific district, this is the only one having an engine with cylinder-stroke greater than twice the diameter. The stroke is equal to or less than the diameter in 22 out of 59 engines. The most common cylinder proportions for small engines are 6″ by 6″, 8″ by 8″, 9″ by 9″, and 10″ by 10″.

BOILERS.

Of 98 boilers in steamers of over 1,000 tons 8 are oval and 90 cylindrical. Of the 90 cylindrical 15 are returned as fire-box and cylindrical boilers. Tubular boilers have largely displaced flue-boilers. The boilers of the side-wheel boats commonly range from 7′ to 10′ in diameter and 18′ to 30′ long; and for the screw steamers with compound engines the boilers range from 10′ to 13′ in diameter and average about 10′ long. The two largest river boats in the Pacific district have cylindrical tubular boilers 7′ in diameter and 32′ long, one boiler in each boat, but the boats in ocean and ferry service usually have short return-tubular boilers in sets. There are 6 single boilers, 7 sets of 2, 1 set of 3, 6 sets of 4, 1 set of 5, 3 sets of 6, 1 set of 8, and 2 sets of 10 boilers. The smallest diameter of boiler used is 3′ 6″, one of the ferry-boats—the "Thoroughfare"—being fitted with 5 such boilers, each 16′ long, and allowed 100 pounds pressure. Of the larger boilers those of sea-going vessels are commonly thicker than the ferry-boat boilers and carry heavier pressures for the same diameter of shell. Excepting a set of 8 new steel boilers upon the ferry-boat "Solano," all of the boilers in this class are of iron. Pressures allowed range from 120 pounds (river-boat boilers) to 25 pounds (in a large ferry-boat boiler), 50 pounds being allowed for the steel boilers mentioned, which are 7′ in dameter and of 0″.36 thickness of shell. The two large river steamers of the Columbia river may be compared with some of the Mississippi steamers, for example:

	Name.	Locality.	Stated tonnage.	Length.	Breadth.	Depth.	Non-condensing-engines.	Cylinders.	BOILERS. Kind.	Diameter.	Length.	Material.	Pressure allowed.
										Feet.	Feet.		Pounds.
1	Wide West	Portland, Oregon	1,200.80	218′.2	39′.5	8′.2	2	28″ by 8′	1 tubular	7	32	Iron	120
2	R. R. Thompson	Dallas, Ohio	1,158.04	215′.0	38′.0	9′.6	2	28″ by 8′	do	7	32	do	120
3	W. P. Halliday	Saint Louis, Mo	1,375.40	287′.4	40′.8	8′.6	2	$24\frac{1}{4}$″ by 10′	5 two-flue	$3\frac{1}{2}$	30	Steel	175
4	City of Helena	Saint Louis, Mo	1,058.28	266′.0	46′.6	7′.8	2	26″ by 8′	5 four-flue	$3\frac{2}{3}$	26	Iron	122

The shells of the boilers in the two former cases are one-half inch thick; in the two latter $\frac{26}{100}$″ and $\frac{14}{48}$″, respectively. The difference in boilers is a characteristic one, and shows how in the usage of different sections similar conditions and requirements may be met by widely-different practice. The volume of boilers is 122.96 cubic feet for the two Mississippi and 136.74 cubic feet for the two Columbia river steamers, despite the greater number of boilers upon the former, and the heating surface is relatively greater in the tubular boilers. But the cylinder surface of the ten small flue-boilers is more than twice as great as that of the two tubular boilers of larger volume.

Of 43 boilers in steamers of between 500 and 1,000 tons, the great majority are cylindrical tubular boilers, 9 being fire-box boilers. There are four oval boilers and there is one rectangular boiler, a type which is becoming obsolete. This boiler is upon the steamer "Wilmington", built in 1865 at Wilmington, Delaware, and now plying between San Francisco and Panama. The steamer is of 940.76 tons with a condensing beam-engine, cylinder 44″ diameter, 6′ stroke (comparatively short), and the single boiler is 18′ wide, 9′ 6″ high and 13′ 9″ long, shell $\frac{5}{16}$″ thick, pressure allowed 25 pounds. The boats of the Columbia and Willamette rivers have almost invariably long tubular boilers ranging in diameter from 3′ 10″ to 5′ 4″ and in length from 20′ to 32′, a single boiler to a boat, except in the case of one ferry-boat which has three tubular boilers each 4′ 4″ diameter by 16′ long. In the San Francisco district most of the ferry-boats have long tubular boilers, the diameters (ranging from 5′ 6″ to 11′ 6″) being greater than in the river-boat boilers of the Willamette district. For ocean service the usual form of boiler is the return-tubular with a length about equal to its diameter. The range of pressure allowed per square inch is from 100 to 150 pounds in river-boat boilers, 35 to 100 pounds in the ferry-boat boilers, and 25 to 80 pounds in the boilers of ocean steamers, in which, however, the pressure will average greater than in the ferry-boat boilers. There are in this class six sets of 2, one set of 3, and one set of 4 boilers, the remaining boilers being used singly.

In order to emphasize the difference of practice on the Columbia and Mississippi rivers the nineteen river steamers of this class in the Willamette district are compared with nineteen boats of similar tonnage in the Saint Louis district, as follows: Aggregate tonnage of the nineteen: Saint Louis, 12,219.83; Willamette, 12,205.49. Each steamer in both cases has 2 engines, and all are simple high-pressure non-condensing engines except 2 Hartupee compound moderating engines on a Saint Louis boat. Average diameter of cylinder, Saint Louis, 20″.82; Willamette, 17″.71. Average length of stroke, Saint Louis, 77″.05; Willamette, 72″.32. Average volume of cylinder, Saint Louis, 33.01 cubic feet; Willamette, 19.03 cubic feet. Ratio, number of boilers to number of boats,

Saint Louis, 3.79; Willamette, 1.10. Average diameter of boiler, Saint Louis, 39″.02; Willamette, 56″.58. Average length of boiler, Saint Louis, 24′.73; Willamette, 26′.06. Average volume of boiler, Saint Louis, 208.85 cubic feet; Willamette, 440.58 cubic feet. Aggregate volumes of boilers, Saint Louis, 15,037.53 cubic feet; Willamette, 9,241.73 cubic feet. Average pressure allowed, Saint Louis, 140 pounds; Willamette, 126 pounds. Thickness of boiler-shell (average), Saint Louis, 27.2 hundredths, and Willamette, 35.5 hundredths of an inch. The boilers of the Willamette steamers are nearly all tubular, and of the Saint Louis steamers all are flue-boilers, some with four or five but the majority with only two flues. The boilers specified are all of wrought-iron plate except in one Saint Louis boat, which has boilers of low steel or homogeneous iron.

In steamers of between 100 and 500 tons in the Pacific district there are 158 boilers, only 4 of them being of steel. Forty-two are returned as fire-box boilers. There is 1 oval boiler. Most of the boilers are either direct- or return-tubular. Of 22 boilers in the Puget sound district, 1 is a return-flue 8′ 10″ diameter and 24′ long (upon an ocean steamer), 1 a fire-box flue and tubular, 7′ 2″ diameter by 18′ long (upon an ocean steamer), 10 fire-box return-tubular and fire-box tubular, and 10 return-tubular boilers. The material is usually specified as Tennessee flange iron or as American C. H., No. 1. I note the following examples: One marine fire-box return-tubular, 14′ 8″ diameter by 18′ long with beam condensing-engine on paddle-wheel boat, 150′ long by 30′ wide by 10′ deep, built in 1849, at New York; 1 fire-box flue and tubular, 7′ 2″ by 18′, with beam condensing-engine on side-wheel boat, 129′ 5″ by 21′ by 8′ 9″, built in 1866, at Sitka, Alaska; 2 fire-box tubulars, 6′ by 22′ with vertical condensing-engine on paddle-wheel boat, 120′ by 24′ by 12′, built in 1869, at Point Discovery, Washington territory; 1 marine return-flue, 8′ 10″ by 24′, with beam condensing-engine on paddle-wheel boat, 166′ by 29′ by 10′.35, built in 1871, at San Francisco; 4 return-tubulars, 3′ 6″ by 16′, with non-condensing engines on paddle-wheel boat 132′ by 28′ 2″ by 9′ 8″, built in 1874, at Portland, Oregon; 2 fire-box return-tubulars, 4′ by 20′ 3″, with vertical condensing-engine on screw-boat, 136′ by 26′.08 by 12½′, built in 1876, at San Francisco; and 1 fire-box tubular, 3′ 8″ by 17′ with non-condensing-engines on paddle-wheel boat, 80′.2 by 19′.2 by 4′.7, built in 1876, at Seattle, Washington territory.

In the Willamette district every boiler in boats of this class is a tubular boiler.

Only 24 out of 158 boilers in this class are over 6′ in diameter, and these are peculiar to ocean or coasting steamers.

In steamers of from 50 to 100 tons there are 61 boilers, mainly cylindrical tubular. None are of steel. Fifteen are specified as fire-box boilers. In steamers of from 25 to 50 tons there are 39 boilers, all horizontal tubular, except 1 fire-box flue and tubular and 1 vertical tubular boiler. In steamers of less than 25 tons there are 48 boilers, only 2 of them being of steel, and 14 being vertical tubular boilers.

The steel boilers of the "Modoc" (468.27 tons) and the "Apache" (468.27 tons), of the Sacramento river service, are 61¾″ diameter by 26′ 4″ long; 2 boilers on each boat; material, Otis steel, double-riveted and plated inside; shells, ⅜″ thick; pressure allowed, 80 pounds. These boilers are of the fire-box and cylindrical type, similar to locomotive tubular. For river service, San Francisco authorities pronounce this style of boiler to combine the "greatest lightness with the greatest serviceable qualities and strength."

MARINE BOILERS OF SAN FRANCISCO.

Through the courtesy of Mr. James Hillman, inspector of marine boilers at San Francisco, California, I am enabled to present the following classification of boilers in use on the different classes of steamers at that port. This enumeration was made subsequent to the close of the census year:

Description.	Ocean passenger.	Inland passenger.	Ferry.	Freight.	Freight and towing.	Towing.	All classes.
Cylindrical tubular	2	22	4	4	3	12	47
Cylindrical, with furnaces and tubes	16	1	2	4	......	4	27
Cylindrical flue and tubular	1	6	1	1	1	4	14
Cylindrical flue	......	......	1	......	......	......	1
Vertical tubular	......	4	......	......	3	......	7
Fire-box cylindrical tubular	......	25	2	5	5	2	39
Fire-box cylindrical flue and tubular	4	......	10	5	......	14	33
Fire-box cylindrical flue	......	......	4	......	......	......	4
Fire-box flue and return-tubular	......	1	......	......	......	1	2
Oval tubular	1	......	......	1	......	......	2
Oval, with furnaces and tubes	2	......	......	......	......	......	2
Oval flue and tubular	......	......	......	1	......	......	1
Rectangular tubular	1	......	......	......	......	......	1
Rectangular, with furnaces and tubes	......	1	......	......	......	1	2

POWER AND SPEED OF ENGINES

The boiler volume in cubic feet per ton of vessel is 5.01 in the "Orizaba," 3.31 in the "Geo. W. Elder," 2.82 in the "Dakota," 2.78 in the "State of California," 2.74 in the "City of Tokio," while it is 0.69 in the "Thoroughfare," 0.87 in the "Victoria," 2.14 in the "Wide West," 1.61 in the "Ancon," and 1.78 in the "Colima." The number of tons of vessel per cubic foot of cylinder space is 4.91 in the "Orizaba," 4.97 in the "Dakota," 6.43 in the "Newark," 8.22 in the "Solano," 10.40 in the "City of Tokio," 13.78 in the "State of California," 17.27 in the "Geo. W. Elder," 19.43 in the "Oregon," 17.56 in the "Wide West," 27.43 in the "Thoroughfare," and 33.85 in the "Victoria." These figures are stated separately to show how widely these ratios range for the various classes of service. The character of the vessels specified will be recognized from previous statements. If we take the boiler volume into the allowed pressure as the criterion of relative boiler power per ton, the boiler power per ton is shown relatively in the following figures:

Geo. W. Elder	264.80
State of California	222.40
City of Tokio	178.10
Wide West	136.80
Orizaba	100.20
Dakota	70.50
Thoroughfare	69.00
Victoria	65.25

In like manner, we may find that the cylinder capacity per ton of vessel (considering the steam-pressure allowed) is represented relatively by the following figures:

Wide West	6.83
City of Tokio	6.03
State of California	5.80
Dakota	5.03
Geo. W. Elder	4.63
Orizaba	4.07
Thoroughfare	3.64
Victoria	2.22

The nominal horse-power per ton as stated in the list of merchant steam vessels of the United States is for the

State of California (2,266.03 tons, 1,800 horse-power)	0.79
Dakota (2,135.04 tons, 2,000 horse-power	0.94
Orizaba (1,244.08 tons, 500 horse-power)	0.40
Thoroughfare (1,012.27 tons, 400 horse-power)	0.39
Victoria (1,462.13 tons, 500 horse-power)	0.34

These nominal powers are, however, neither well defined nor consistent with any uniform rule.

Of 25 steamers of over 1,000 tons of the port of San Francisco, the average length of stroke is about $7\frac{1}{2}'$; average boiler-pressure, about 58 pounds. For a total tonnage of 52,990 tons the cylinder volume is 5,327.69 cubic feet, nearly half of which is in compound cylinders, the rest being in simple cylinders of long stroke. The aggregate nominal power is about 29,000 horse-power.

The "City of Tokio," 5,079.62 tons. This and the "City of Pekin" are the largest ocean steamers of the Pacific district. At 55 revolutions, 60 pounds initial, 10 pounds terminal, the engines of each vessel develop 4,000 indicated horse-power.

The "State of California," 2,266.03 tons. The engines of this ocean steamer, running at 63 revolutions, with 74 pounds per square inch boiler-pressure, developed an indicated horse-power of 1,500.08. With 80 pounds pressure, 73 revolutions, and a later cut-off, 2,323.83 horse-power were developed. The following data of these trials is derived from a communication of Mr. J. Haug, marine engineer, to the *Nautical Gazette*.

The following are the particulars of the engines of the "State of California":

Diameter of high-pressure cylinder	inches..	42
Area	square inches..	1,385.44
Diameter of low-pressure cylinder	inches..	73
Area	square inches..	4,185.4
Ratio of cylinders		3.021
Stroke	feet..	$4\frac{3}{12}$

Constants for power:

$$\frac{1385.44\times2\times4\frac{1}{4}}{33,000} \text{ for high pressure cylinder} = 0.356856;$$

$$\frac{4185.4\times2\times4\frac{1}{4}}{33,000} \text{ for low-pressure cylinder} = 1.07806.$$

The cards are shown in Fig. 27. The particulars of the cards are:

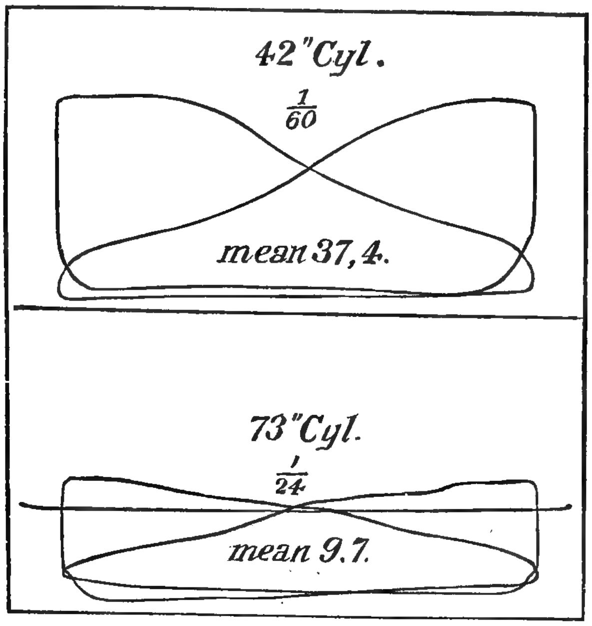


FIG. 27.

Boiler-pressure, per square inch	pounds..	74
Receiver, per square inch	do....	+9½
Vacuum	inches..	27
Cut-off	do....	23
Mean pressure in high-pressure cylinder	pounds..	37.4
Mean pressure in low-pressure cylinder	do....	9.7
Revolutions per minute		63
Indicated horse-power—		
Of high-pressure cylinder	0.356856×37.4×63=	841.32
Of low-pressure cylinder	1.07806×9.7×63=	658.76
Total		1,500.08

The following are the particulars of other cards taken from this engine:

Steam	68	73	80
Vacuum	27½	26	24
Receiver	+3½	+14½	+18
Cut-off	23	39	35
Revolutions	58	68	73
Power high-pressure cylinder	814	891.71	1,049.51
Power low-pressure cylinder	572	932.41	1,274.32
Total indicated horse-power	1,386	1,824.12	2,323.83

The "Solano," 3,549.31 tons. This great ferry-boat has a piston area of nearly40 square feet (in two cylinders). The new steamer "Pilgrim" has a piston area of nearly 66 square-feet in one cylinder, and is expected to develop 6,500 horse-power; but the speed of the engine will be greater than in those of the "Solano," which, in the merchant list of steam vessels of the United States, is credited with a nominal horse-power of 2,000.

The "Oakland," 1,672.24 tons, is a ferry-boat plying between San Francisco and Oakland, and having beam-engines, condensing.

The "Garden City," 1,080.70 tons, is a ferry-boat plying between San Francisco and Alameda. It has a beam-engine, condensing, and with a very small bore for the length of stroke.

The "City of Chester," 1,106.21 tons, is a screw steamship plying from San Francisco to Victoria, British Columbia. It has a compound engine with surface-condenser.

The "Wide West," 1,200.80 tons, is a paddle-wheel boat of the Columbia River, Oregon. It has two 28″ by 8′ engines, and is allowed a boiler-pressure of 120 pounds.

Of small boats and their engines we note the following examples:

The "Sansalito," 692.43 tons, is a ferry-boat plying between San Francisco and Sansalito. It has one beam-engine, 50″ by 11′, condensing.

The "Champion," 634.09 tons, is a paddle-wheel passenger-boat plying on the Willamette river, from Portland to Eugene City, the Cascades, and Woody island. The power is small, the boat having a steam cylinder volume of only 8.54 cubic feet in two 14″ by 4′ engines, and the boiler-pressure allowed being 110 pounds.

The "Alexander Duncan," 236.76 tons, is a passenger-steamer coasting from San Francisco to Humboldt bay and to San Diego. It is driven by a pair of compound engines.

The "Goliah," 235.86 tons, is a Puget sound passenger-boat with side-wheels, and a beam-engine.

The "Tiger," 85.37 tons, is a side-wheel tug- and passenger-boat with direct-acting engines.

The "Neponsett," 60.22 tons, is a Sacramento river freight-boat, a propeller driven by two non-condensing engines.

The "Fearless," 95.40 tons, is a towing-boat, plying from Empire City to Gardiner and the head of navigation from Coos bay. It is a propeller and has a compound engine.

The "Gov. Irwin," 80.94 tons; the "C. M. Small," 97.99 tons; the "Donald," 148.30 tons, and the "H. H. Buhne," 97.72 tons, are San Francisco towing-boats, the first a screw-tug, the second a stern-wheel boat, and the others screw-tugs. The cylinder capacity of the "Gov. Irwin" is 5.30 cubic feet, of the "C. M. Small" 6.29 cubic feet, of the "Donald" 8.83 cubic feet, and of the "H. H. Buhne" 10.54 cubic feet. On account of the higher speed the small propellers develop more power from the same cylinder capacity under the same boiler-pressure than is practicable with the stern-wheel boats.

The following data of the "City of Pekin" may be compared with the data of English steamers elsewhere cited: Cylinders, two 51″ and 88″ by 54″ stroke; 495′ piston speed; 10,000 square feet condensing-surface; Hirsch screw, 20¼′ diameter, 30′ pitch; 60 pounds boiler-pressure; 10 boilers, 13′ shell by 10½′ long, with 30 furnaces and 2,040 tubes, each 3¼″ outside diameter; grate-surface, 520 square feet; total heating-surface, 17,000 square feet. At 4,000 horse-power using 80 tons coal, shows a consumption of 1.86 pounds per horse-power per hour. The heating-surface per indicated horse-power is 4.25 square feet. The boiler volume is 13,936.96 cubic feet, 3.48 per indicated horse-power; ratio surface to volume, 1.22; grate-surface per indicated horse-power, 0.13 square feet; condensing-surface per indicated horse-power, 2½ square feet.

Of the boiler power of steamers of the Pacific district, the volumes and dimensions of boilers have been stated at some length, and the styles employed in various classes of service have been remarked upon. They are mainly tubular boilers, either of the marine (return-tubular) or locomotive (fire-box and cylindrical) types. The heating-surface of boilers per indicated horse-power of engines increases with the decrease in size of boilers and engines.

Were proportions similar for all sizes of boilers the volumes would increase as the third and the surfaces as the second powers of linear dimensions. In the Pacific district the average volume of a single boiler is, for steamers of over 1,000 tons, 1,368.91 cubic feet; steamers from 1,000 to 500 tons, 791.25 cubic feet; steamers from 500 to 100 tons, 349.75 cubic feet; steamers from 100 to 50 tons, 201.85 cubic feet; steamers from 50 to 25 tons, 157.03 cubic feet; steamers of 25 tons and under, 58.70 cubic feet. If for a boiler of 1,368.91 cubic feet volume the ratio of heating-surface to boiler-volume be 1.22 and the heating-surface per indicated horse-power of connected engines be 4.50 square feet, in the smaller boilers we would have for similar proportions and pressures:

Volume of boiler.	Ratio heating-surface to boiler volume.	Heating-surface per indicated horse-power.
Cubic feet.		*Square feet.*
791.25	1.46	5.40
349.75	1.92	7.09
201.85	2.28	8.41
157.03	2.51	9.27
58.70	3.39	12.52

At the same rating the heating surface per indicated horse-power would be about 25 square feet for the smallest boiler in the district, a boiler on the steam yacht "Magnet," which is allowed 125 pounds pressure. This yacht has a 4″ by 4″ engine, a size commonly rated at 4 horse-power, but which, under high pressure, might develop 6 horse-power or more. The heating-surface in the boiler can scarcely exceed 40 square feet, but some boats with 4″ by 4″ engines have three times as large boilers.

In rating heating-surface of boilers by horse-power of engines everything depends upon the amount of steam required by the engines, and as the smaller engines are, as a rule, much less economical than the large compound engines of ocean steamers, they would require a much greater heating-surface for indicated horse-power were it not for the higher average of pressures employed in the smaller boilers, especially of river boats. In the long flue-boilers commonly in use in the Mississippi valley the heating-surface is of course much less relatively to the boiler-volume than in the tubular boilers used upon the rivers of the Pacific seaboard.

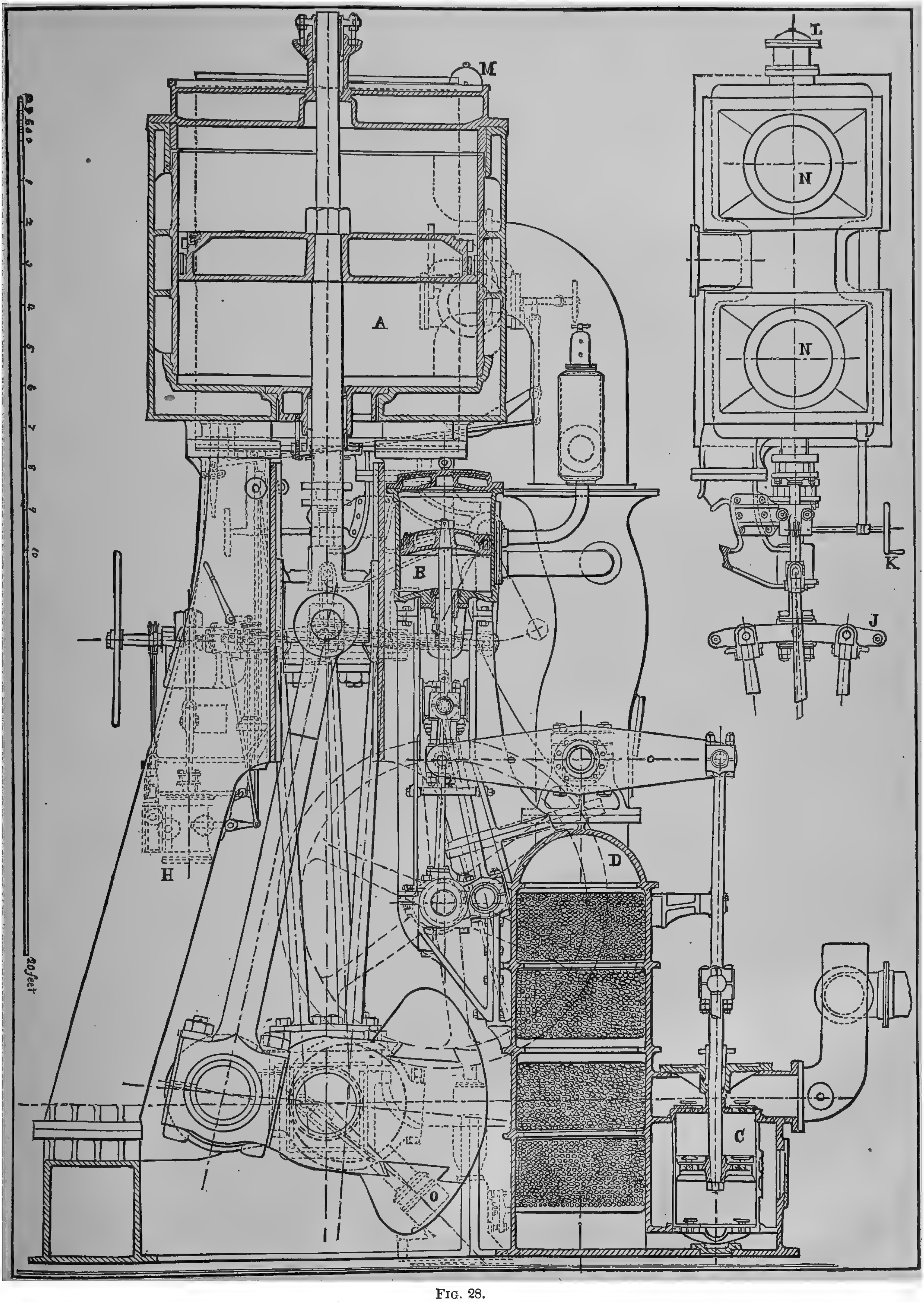


FIG. 28.

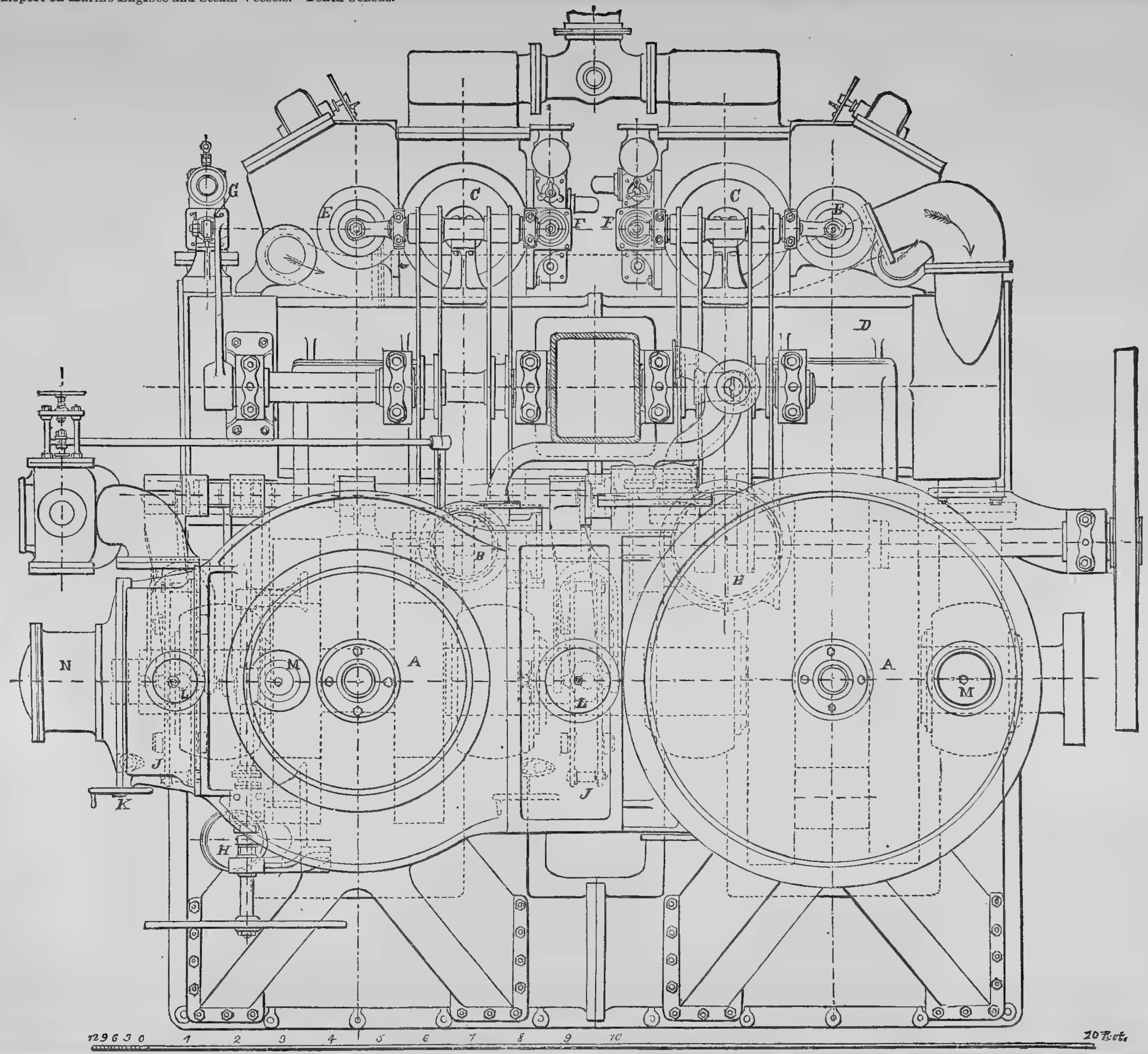


Fig. 29.

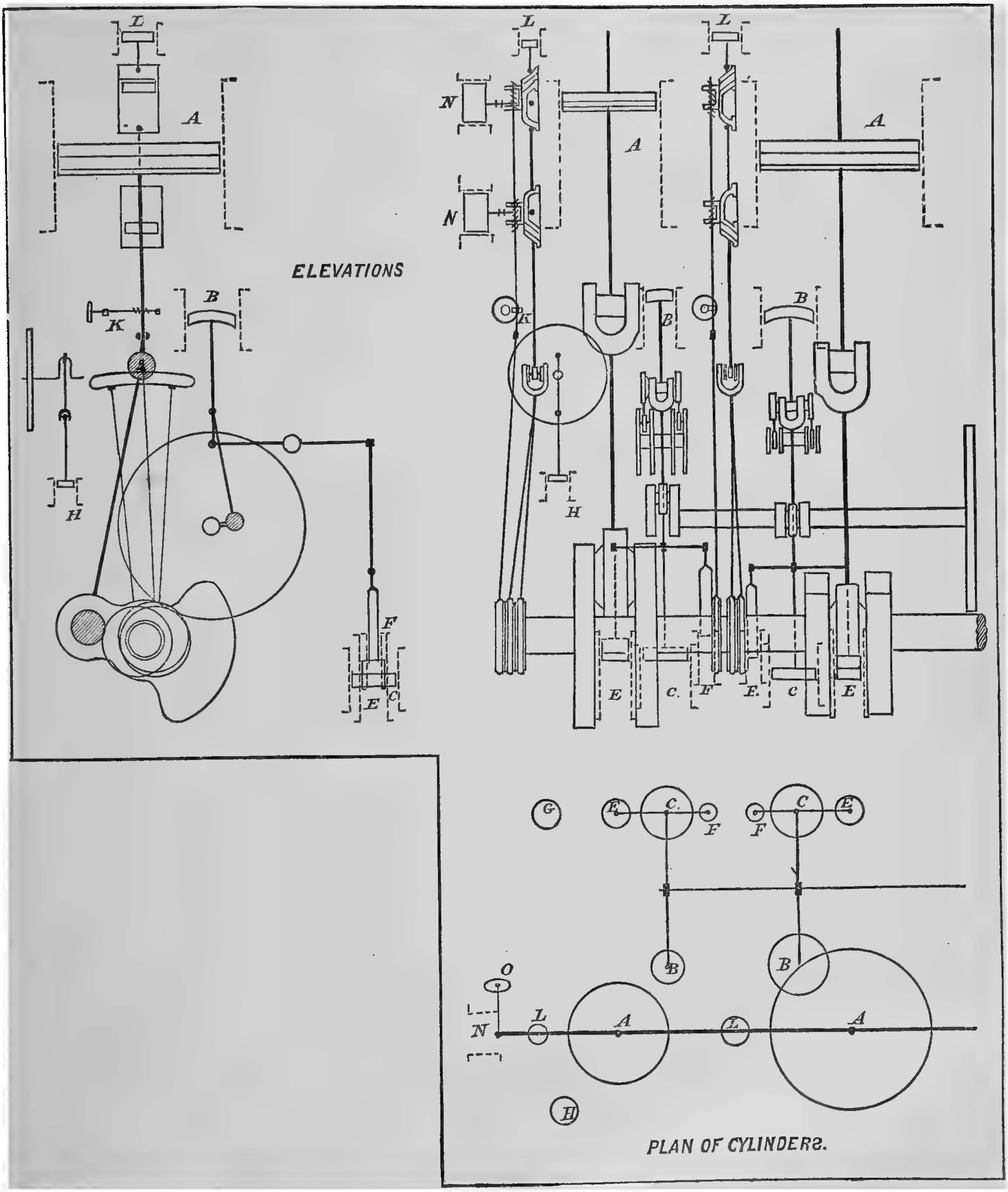


FIG. 30.

ENGINES OF A PACIFIC MAIL STEAMSHIP.

A description is here adduced of the engines of the Pacific mail steamship "City of San Francisco," built by John Roach & Son, at Chester, Pennsylvania. Three drawings are presented, an elevation looking aft (Fig. 28) and a plan of the engine (Fig. 29) (these have previously appeared in the London *Engineering*) and a skeleton sketch or drawing in plan and two elevations (Fig. 30), showing the inter-relations of the various moving parts, and the arrangement of pumps, valve-gears, and auxiliary engines.

The machinery embodies three engines in one and five steam cylinders, two of the engines being compound. The letters A A indicate the cylinders of the principal engine. The smaller or high-pressure engine is surrounded by an annular space which serves as a receiver between high- and low-pressure cylinders. The linings within which the pistons work are cast separately and bolted in, and the cylinders are steam-jacketed—sides, tops, and bottoms. This main engine is of simple arrangement, for, beside driving the propeller, its only duty is to operate a bilge-pump, indicated by the letter O upon the drawings. This is conveniently driven from the forward end of the main crank-shaft. There is a reversing engine, H, and a compound pumping-engine, B B, with its receiver and valve-gears conveniently located under the large cylinders. This drives two air-pumps, C C, two circulating-pumps, E E, two feed-pumps, F F, and a bilge-pump, G. This independence of the pumps has several advantages. The pumps are not affected by racing of the main engines in rough weather, both pumping- and reversing-engines being governed by fly-wheels, as shown in the illustrations. The piston areas and cylinder volumes are given as follows comparatively, so that their relative capacities may be seen at a glance:

	Diameter.	Stroke.
	Inches.	*Feet.*
Main high-pressure cylinder	51	5
Main low-pressure cylinder	88	5
Pumping high-pressure cylinder	16	2
Pumping low-pressure cylinder	27	2
Starting-engine cylinder	10	1
Air-pumps (single acting)	24	2
Circulating-pumps (double acting)	$14\frac{1}{2}$	2
Feed-pumps (single acting)	6	2
Bilge-pumps (single acting)	6	2
	8	$13\frac{1}{2}$

Main and pumping engines make the same number of revolutions, and their piston speed is therefore as 5 to 2. The volumes swept by the pistons per revolution are as follows:

	Cubic feet (actual).	Relative to main engine cylinders.
Main engine cylinders	1.0000	564.190
Main high-pressure cylinder	0.2514	141.860
Main low-pressure cylinder	0.7486	422.330
Pumping engine	0.0381	21.486
Pumping high-pressure cylinder	0.0099	5.580
Pumping low-pressure cylinder	0.0282	15.906
Starting engine	0.0019	1.088
Two air-pumps	0.0223	12.568
Two circulating-pumps	0.0163	9.184
Two feed-pumps	0.0013	0.784
Two bilge-pumps	0.0013	0.777

This table furnishes an interesting comparison of the relative power employed in pumping and propelling service, which appears about as 1 to 26, and of the relative capacity of pumps. Taking the feed-pumps as a standard of comparison, the bilge-pumps have about the same capacity, but the bilge-pump O may be disconnected when desired. The capacity of the circulating-pumps is about $12\frac{1}{2}$ and of the air-pumps about 17 times as great, of the starting engine $1\frac{1}{2}$, pumping engine about 29, and main engine about 770 times as great.

The valves of the main cylinders are single-ported valves, cutting off at about two-thirds stroke, with plain plate expansion valves arranged to reduce the cut-off to one-tenth when desired. The change of cut-off is effected by right and left screws operated by a screw and worm wheel, the latter upon the expansion valve rod, as shown at K in the figures. The main valves are counterbalanced for weight by the steam pots shown at L L, which have a piston diameter of $8\frac{1}{2}''$ for the high, and $15\frac{1}{2}''$ for the low-pressure cylinder, and the valves of the high-pressure cylinder have the pressure upon their faces counteracted by being connected by links with the pistons of vacuum pots indicated by the letter N in some of the figures. These have a diameter of 20″ each. The main valves are

driven by a pair of eccentrics and double-bar link, making the travel of the valve equal that of the eccentric when the link is in full gear. The travel of the high-pressure main valves is 10″, expansion valves 12″, low-pressure main valves 12″, expansion valves $14\frac{1}{2}$″. The high-pressure steam ports are $4\frac{1}{2}$″ wide by 36″ long, cut-off ports $2\frac{3}{4}$″ wide by 33″ long. The low-pressure steam ports are $5\frac{1}{2}$″ wide by 60″ long. Main and cut-off valves are held to their faces by bars bolted at their backs, and the cut-off valves by flat springs. The expansion eccentrics are set opposite the crank pins and the eccentric rods lead direct to the valve-stems. The auxiliary engines, pumping and starting, have plain slide valves cutting off at two thirds stroke and operated, the former by single and the latter by a pair of eccentrics with links which are not shown upon the skeleton sketch. The reversal of the main engines is effected by the shifting of the valves by the small starting engine H, which operates through a reversing screw fitted with a cross-head, which is connected to a rock-shaft and reversing links. The starting engine is itself fitted with self-acting reversing gear. To admit steam to the main cylinders for warming them up before starting there are pass-over valves, as shown at M in several views.

The condenser shown at D forms the base of the supporting columns of the frame on the starboard side. It is made in two pieces, each with an air-pump cast on. It is also in two sections, upper and lower, and the water passes twice through its length, the steam first reaching the coldest surface, but being prevented from striking directly against the condenser tubes by a deflecting plate. The exhaust-pipe is of cast-iron and has an expansion joint in the middle. It is 20″ by 25″ in section. The condenser contains 2,380 tinned brass tubes $\frac{3}{4}$″ diameter, 13′ 9″ exposed length, 6,425 square feet condensing-surface.

Eccentrics are of cast-iron, eccentric-straps of wrought-iron, valve-spindles of steel. The valve-facings of the main engines are of hard cast-iron and are bolted on. The piston-rods of the main engines have their lower ends forked and fitted with brasses $9\frac{1}{2}$″ in diameter and 14″ long and with caps, bolts, nuts, and gibs for wearing on the guides. Condenser tube-plates are of hard cast-iron $1\frac{7}{8}$″ thick and the tubes are packed with paper packing. The bed-plate of the engine is cast in two sections, and upon each are two pillow-blocks with journals 17″ in diameter and 26″ long. The bottom brasses of these are set in removable chocks, so that they may be taken out without removing the shaft. The crank-shaft is made in pieces and shrunk together; line shaft is 16″ in diameter; crank-pins 16″ in diameter by 18″ long. Crank-shaft counterbalances are forged on.

PROPORTIONS AND ARRANGEMENT OF STEAMERS.

The following twenty-four examples of steamers of over 1,000 tons are arranged in the order of lengths relative to breadths:

Name.	Ratio length to breadth.	Ratio breadth to depth.	Tonnage.	Class of service.	Method of propulsion.	Where built.	Date of build.
Victoria	10.23	1.76	1,462.13	Ocean	Screw	Hull, England	1866
City of Tokio	9.85	1.51	5,079.62	do	Screw (ship)	New York	1874
State of California	8.78	1.38	2,266.03	do	do	Philadelphia, Pennsylvania	1879
Geo. W. Elder	8.77	1.32	1,709.59	do	do	Chester, Pennsylvania	1874
City of New York	8.43	1.42	3,019.56	do	do	do	1875
City of Sidney	8.43	1.44	3,016.76	do	do	do	1875
Transit	7.74	2.68	1,566.81	Ferry	Paddle	Oakland, California	1875
Colima	7.66	1.95	2,905.69	Ocean	Screw (ship)	Chester, Pennsylvania	1873
Oregon	7.57	1.57	2,335.38	do	Screw	do	1878
Granada	7.25	2.00	2,572.38	do	Screw (ship)	Wilmington, Delaware	1873
Orizaba	7.19	2.26	1,244.08	do	Paddle	New York	1854
Dakota	6.75	2.00	2,135.04	do	do	Green Point, New York	1868
City of Panama	6.72	1.80	1,490.21	do	Screw (ship)	New York	1874
Thoroughfare	6.46	3.02	1,012.27	Ferry	Paddle	San Francisco, California	1871
Newark	6.38	3.25	1,783.80	do	do	do	1877
Oakland	6.38	2.59	1,672.24	do	do	do	1875
Bay City	6.25	2.71	1,283.42	do	do	do	1878
Solano	6.21	1.73	3,549.41	do	do	Oakland, California	1874
City of Chester	6.09	2.09	1,106.21	Ocean	Screw (ship)	Chester, Pennsylvania	1875
Capitol	5.90	4.31	1,989.20	Ferry	Paddle	San Francisco, California	1866
R. R. Thompson	5.66	3.96	1,158.04	River	do	Dallas, Oregon	1878
Ancon	5.65	2.27	1,540.78	Ocean	do	San Francisco, California	1868
Garden City	5.62	2.72	1,080.70	Ferry	do	do	1879
Wide West	5.52	4.82	1,200.80	River	do	Portland, Oregon	1877

The largest steamships under the American flag are in the Pacific district. The "City of Pekin" and the "City of Tokio" are each of 5,079.62 (registered) tons burden, and ply between San Francisco and Hong-Kong, Yokohama, and other ports. The relative size of these vessels may be compared with that of other large American steamers. The "Solano" (ferry-boat), of this district, is of 3,549.41 tons. The "City of Rio Janeiro," 3,548.30 tons, and the "City of Para," 3,532.25 tons, are the largest steamers of the New York district. The "Pilgrim," of the Fall River

line, is of about 3,500 tons burden; the "Bristol" and the "Providence" each 2,962.20 tons. The tonnage of the "Daniel Drew" is 2,902.24; of the "Rhode Island," 2,742.42. The "Pennsylvania," of the American line (trans-Atlantic), is of 3,104.28 tons. The largest coasting steamers are the "Chalmette,"2,982.96 tons, and the "Louisiana," 2,840.33 tons. On the Mississippi we have the "James Howard," 2,321.44 tons, the "J. B. M. Kehloe," 2,293.78 tons, and the "Ed. Richardson," 2,048.34 tons; and on the lakes, of the Buffalo and Chicago line, the "Rochester," 2,220.05 tons, and the "Commodore," 2,082.02 tons. In 1860 the only English steamer exceeding 3,500 tons was the "Great Eastern," whose registered tonnage was 13,344 tons, and at present the new English (Cunard) steamer "Sahara," 7,500 tons, is the nearest approach to this enormous tonnage.

It will be seen that the "City of Pekin" and the "City of Tokio" are very large steamers, even when compared with the mammoths of English engineering skill. The "City of Pekin" is 423′ long and 48′ broad; the Cunard steamer "Gallia" is 450′ long and 44′ broad, and the "Sahara" 500′ long and 50′ broad. In the "City of Pekin" the boilers occupy some 60′ of the length of the vessel in the hold, being set, as usual, five on each side, cylinders transverse to the length of the steamer, and a fire-room in the middle. The boilers are of the usual type for large sea going vessels, compound return-tubular, three furnaces to a boiler, and five boilers on each side of the steamer; the engine-room abaft or back of the boiler-room, and the main deck above the boiler-room. The bunkers will contain 1,500 tons of coal, which, rated at 50 pounds (heaped) per cubic foot, would occupy 67,200 cubic feet, equal to a cube of about 41 feet, or a parallelopipedon 20 by 20 by 168. This would leave over twice as much space for cargo below the main deck, allowing for boiler and engine space. It may be remarked that the bunkers of the Cunard "Gallia" have space for 1,700 tons of coal. The "City of Pekin" is arranged to accommodate 150 cabin and 1,800 steerage passengers.

The "Solano" is the largest ferry-boat in the world. The boat was built at Oakland, but the steam machinery was built at Wilmington, Delaware. It will take 48 freight-cars at a time, and has about five times as much deck space as one of the large Jersey City ferry-boats.

The dimensions of some smaller steamers are as follows:

	Tonnage.	Length.	Breadth.	Depth.
		Feet.	*Feet.*	*Feet.*
Sansalito	692.43	205.5	32.0	9.8
Willamette Chief	693.19	163.0	35.8	5.4
Arcata	560.21	180.0	26.2	8.6
S. T. Church	555.99	154.0	36.0	5.3
Los Angeles	493.00	170.0	27.0	11.0
Almota	502.35	157.0	36.0	5.0

All of these have paddle-wheels except the "Los Angeles," which is a screw-propeller. The stern-wheel boats are usually of lighter draft than those with side-wheels. Of the engines of the above boats the "Sansalito" has one vertical beam-engine 50″ diameter by 11′ stroke; the "Willamette Chief," two 20″ diameter by 5′ stroke direct acting engines. The "Arcata" has one compound engine 14½″ and 20″ diameters of cylinder by 28″ stroke. The "S. T. Church" has two 17″ diameter by 6′ stroke direct-acting engines. The "Los Angeles" has one compound engine 19¾″ and 43⅝″ diameters of cylinder by 28″ stroke. The "Almota" has two 16″ by 6′ direct-acting engines. Of these steamers the river boats are most bluff in build, the ratios of length to diameter being for the "Willamette Chief," "S. T. Church," and "Almoto" 4.55, 4.27, and 4.36, while the ratio is for the "Sansalito" (ferry-boat) 6.42, the "Arcata" (ocean passenger) 6.87, and the "Los Angeles" (inland passenger and coaster) 6.29. The "Santa Cruz," a freight-boat on the same route as the "Los Angeles," and having similar machinery, is a much shorter boat, the ratio of length to breadth being only 4.58.

The Sacramento river boats have usually a greater breadth for the length than those on the Columbia river. A comparison from averaging a number of them, all vessels of nearly 500 tons, gives the showing: ratio of length to breadth, 4 for the Sacramento and 5½ for the Columbia river boats considered. The stern-wheel boats will be more fully considered under the head of Mississippi valley steamers. A Sacramento river stern-wheel steamer of recent build and which may be taken as a type of the river steamers of the Pacific seaboard, is 180′ long by 40′ wide and about 8′ deep, with a draft from 3′ to 4½′ according to load, the carrying capacity being 300 tons. It has a saloon deck 136′ long by over 30′ wide, of which length 36′ is in open decks and 100′ in cabins of 10′ height, a forward cabin 30′ wide, and an aft-cabin 14′ wide, lined with state-rooms. The boat is upward of 450 tons burden. The "City of Stockton," running from San Francisco to Sacramento or Stockton, is of unusually short build for a passenger-boat, viz: 175′ long, 50′.8 broad, and 8′.15 deep; tonnage, 485.63; ratio length to breadth, 3.44. It was built at Stockton, 1876. Another very wide boat is the beam-engine ferry-boat "Carquinez," 102 tons, plying between Carquinez and Benecia. This boat has length, 82′.6; breadth, 24′.8; depth, 6′; ratio length to breadth, 3.33; and was built at Martinez, California, 1854.

Most of the river boats in the Willamette district have the ratio of length to breadth between 5 and 6. The "Alice," 457.16 tons, and the "E. N. Cook," 415.95 tons, are among those of most narrow build. These boats are

25′ broad and 6′ deep. The "Latona," 128.91 tons, length 90′.4, breadth 18′.4, depth 3′.9, running from Portland to Lewis and Lake river, is the shallowest boat of over 100 tons. The "Astoria," 124.61 tons, length 98′, breadth 24′.4, depth, 10′.5, running from Portland to Shoal Water bay, is an unusually deep boat.

The tendency in tug-boats is for the substitution of screws for paddles, but there are many paddle-boats in the service, especially among the larger tugs. An example of a very narrow tug-boat is the "C. M. Small," a stern-wheel boat with two 12″ by 48″ non-condensing engines. It is of 97.99 tons burden, length 137′, breadth 20′, depth 6′, ratio length to breadth 6.85. The "Daisy Whitelaw," a small steam freight-boat plying between San Francisco and Point Reyes, is of the dimensions 60′.5 by 14′.4 by 8′.6, tonnage 44.42. Boats of 3′ or 4′ draft ply from Celilo to the head of navigation on the Columbia river, but the depth of boats plying from Portland to Eugene City, on the Willamette, does not appear to exceed $5\frac{6}{10}$′, with a draft probably half that, as the stern-wheel boats stand high out of the water. The "Mohave" and "Colorado," running from Yuma to Colorado river landings, have a depth of only 4′, and the "Gila" of only $3\frac{6}{10}$′, although the last is of 236.47 tons burden. The "Little Annie," 85.56 tons, plying to the head of navigation on the Coquille river, has the dimensions: length 67′.51, breadth 16′.47, and depth 4′.21. The "Restless," plying from Winchester bay to the head of navigation on the Umpqua river, has a tonnage of 101.02 tons, length 72′, breadth 16′, and depth $4\frac{1}{2}$′. The largest steamer on lake Tahoe is 92′ long, 16′ 5″ broad, and $4\frac{1}{2}$′ deep. The "Gov. Dana," running to the head of navigation on the Sacramento river, is of 299.77 tons, and of the dimensions: 145′ long, 30′.6 broad, $3\frac{1}{2}$′ deep.

Considering the boats of the San Francisco district alone, the inland passenger steamers built in and prior to 1865 have a ratio of length to breadth 4.72 and to depth 22.32, while for such steamers built in and since 1875 these ratios are 4.19 and 22.60. In like manner, comparing the ferry-boats built in and before 1870 and in and after 1875, we find the stated ratios for the averages to be 5.12 and 16.53 for the earlier and 5.79 and 15.47 for the later built boats. The "Solano" is omitted from this comparison, on account of being designed for a peculiar service.

Of carrying capacity it may be noted that the "Solano" will take a weight of freight-cars equal to upwards of half its registered tonnage; the whaler "Mary and Helen," of $420\frac{1}{2}$ tons, will take 200 tons coal and 2,700 barrels of oil, an equivalent of $6\frac{1}{2}$ barrels of oil and nearly half a ton of coal per ton of vessel. The Sacramento passenger-boat "Modoc" carries, in addition to passengers, about $\frac{2}{3}$ of a ton actual weight of cargo per ton of vessel. Stern-wheel boats, such as the "Modoc," being comparatively flat-bottomed, carry immense amounts of cargo on a light draft.

The steam whaler "Mary and Helen" was built at Bath, Maine, and sent to the Pacific coast, where it was purchased by the United States Government for Arctic service. This steamer is 155′ long, 30′ breadth of beam, $16\frac{1}{2}$′ depth of hold. It has a flush deck, frame of white oak, with planking 6″ thick, and double or 12″ thick forward of the foremast, where it is braced with pointers set 2′ apart from keel to deck, and these in turn are braced with 10″ cross-timbers. On deck there is a galley for the cook on the starboard side, and on the port side a companion-way leads down to the forward cabin, which has state rooms on the port and pantry and engineer's room on the starboard side. Two doors lead into the after-cabin, on the starboard side of which is the captain's cabin. The engine-room, with a vertical engine 20″ by 20″, is between main and mizzen masts, and the boiler, a horizontal return-tubular of 200 nominal horse-power, is in the hold below the engine-room. The boiler extends forward of the engine-room, and above it are the drying-room, sail-pens, and store-room. Oil is stored in the hold forward of the mainmast. There are two donkey-engines for hoisting the anchor, cutting ice, and other work; steam fire-pumps and other accessories. A jet condenser is employed.

The above account will give a fair idea of a steamer of this character. It is of low power, say 7 or 8 knots per hour in speed under steam and against a head-wind, but is intended to be propelled mainly by sail, reserving the coal for use in calms and among the ice-floes.

The Pacific Mail steamship "City of San Francisco," built by Messrs. John Roach & Son, and the machinery of which is elsewhere described, is 352′ long over all, 40′ beam, and 28′ 10″ deep under the spar deck. It is termed a three-deck steamship, having a hurricane deck running all fore and aft, and an orlop deck additional forward, extending from the forward coal-bunker bulkhead to the stem.

The river towing-boats of the Pacific seaboard are almost invariably stern-wheel boats, there being only a few small boats with screw-propellers. The tug-boats of San Francisco and San Pablo bays are nearly all propellers, and there is but one side-wheel tug, the "Tiger," which is of the English type. The "Tiger" has a length of 100′, breadth 21′, depth $5\frac{1}{10}$′, tonnage 85.37 tons. It has three boilers, each $3\frac{1}{2}$′ in diameter by 14′ long, and is driven by two condensing-engines, each 16″ in diameter by 4′ in stroke.

STEAMERS OF THE MISSISSIPPI VALLEY.

Geographical distribution.—The attempt to classify the steamers according to routes of service is attended with difficulty on account of the great number, especially of freight-steamers, which have no definite routes. But although the grouping of steamers may on this account be vague and approximate in some cases, it will still be found valuable as affording tolerably clear ideas of the scope and direction of the great steam service which gives to the Mississippi river system its obvious commercial value. There are, in the first place, the ferries, and, hardly

distinguishable in character of service, the short runs of boats which ply between points not many miles distant. In the second place there is a class of steamers regularly plying between certain large cities over long river routes. In the third place, there is a class of steamers which may be specified as plying mainly upon certain small or tributary rivers or sections of rivers. The grouping of these, if it fails to include all the steamers visiting such rivers, will at least convey some ideas of the magnitude of commerce and the conditions of navigation. In the fourth place there are large numbers of steamers which can only be specified as plying inland from the principal cities. In this expression inland is sometimes understood as meaning up the river, but it sometimes signifies any where in the entire river system.

Steamers.	Steamers.	Tons.	Engines.	Cubic feet.
Ferries and short runs on the lower Mississippi, below the Ohio river, also including steamers plying from New Orleans to the sea and in the New Orleans harbor and local service, the latter being designated by a star.	*1	1,041.20	2	68.74
	10	2,196.00	18	149.92
	*21	3,209.80	29	459.44
	3	208.51	5	8.70
	*6	470.22	10	23.34
	3	117.03	5	5.20
	*2	73.26	2	4.78
	11	166.18	15	8.53
	*9	115.17	10	3.37
Ferries and short runs on the upper Mississippi, including the ferries and local service at Saint Louis.	22	5,035.96	31	410.92
	17	1,223.64	26	64.25
	16	620.15	22	22.07
	11	144.54	15	4.20
Ferries and short runs on the lower Ohio, below Cincinnati.....	[illegible]	3,173.77	6	198.77
	1	746.90	2	40.16
	13	3,172.23	25	190.78
	[illegible]	215.61	[illegible]	6.38
	5	96.62	6	1.20
	1	27.86	1	0.88
Ferries and short runs on the upper Ohio	5	3,426.66	10	175.17
	26	5,166.70	51	278.95
	25	1,761.38	43	70.99
	9	149.11	11	3.44
	19	694.57	24	22.25
Ferries and short runs on the Missouri river......................	10	1,684.24	15	131.08
	12	859.76	20	51.06
	3	99.34	4	5.20
	2	21.15	3	0.66
Plying between Saint Louis and Saint Paul and Stillwater	1	549.21	[illegible]	19.44
	21	3,234.41	42	178.00
	7	639.79	14	38.19
	2	72.62	4	5.84
Plying from Saint Louis, Cairo, and Memphis to Wheeling, Pittsburg, and Cincinnati.	7	4,337.37	14	138.94
	7	1,890.51	14	109.93
	5	168.07	7	5.09
Plying from Saint Louis and other principal ports to Yankton, Omaha, and Sioux City.	16	4,979.26	30	192.54
	1	76.98	2	8.54
	1	44.91	2	1.07
	1	4.00	1	0.03
Plying from Saint Louis and Memphis to New Orleans and Vicksburg.	3	4,521.70	6	280.34
	2	1,231.72	4	91.26
	1	23.83	1	0.98
Plying between New Orleans and Pittsburg, Cincinnati, and other ports of the upper Ohio.	5	5,931.85	10	247.97
	5	3,871.51	10	130.04
	15	4,257.17	32	302.40
	2	122.26	4	8.99
	1	22.62	1	0.54
Plying on Red, Washita, and Atchafalaya rivers................	1	1,200.84	2	66.32
	3	458.17	6	16.90
	2	131.85	3	2.57
	2	82.35	3	2.27
	5	71.62	6	2.34
Plying on the Illinois river. (See also lake steamers)..........	1	114.66	2	6.28
	2	150.72	4	2.84
	2	72.50	2	0.63
	10	84.64	11	1.48

Steamers.	Steamers.	Tons.	Engines.	Cubic feet.
Plying on the Arkansas, White, and Saint Francis rivers	8	1,494.94	16	40.48
	15	1,140.05	26	25.10
	7	288.08	10	4.07
	3	62.20	4	2.79
Plying on the Tennessee river	9	1,952.85	18	62.72
	2	187.53	4	4.59
	5	203.16	8	6.32
	1	21.14	1	0.35
Plying on the Cumberland river	9	2,191.86	17	82.66
	6	488.13	12	16.68
	2	42.90	4	2.30
Plying on the Wabash and White rivers	8	524.91	13	15.65
	5	183.70	7	3.87
	7	117.19	8	4.78
Plying on the Kanawha, Big Sandy, Licking, Kentucky, and Green rivers.	6	1,265.07	14	66.57
	10	740.98	18	41.63
	10	400.16	19	16.[illegible]1
	6	98.78	11	4.0[illegible]
Plying on the Muskingum, Scioto, and Miami rivers	7	1,069.93	14	56.81
	3	193.61	4	2.91
	2	76.24	2	1.56
	3	53.79	3	1.61
Specified as plying upon the Monongahela and Alleghany rivers.	4	1,152.99	8	99.94
	3	214.17	6	10.26
	3	98.50	6	6.39
	4	77.37	8	7.95
Plying on the Osage and Gasconade rivers	1	66.66	2	3.26
	2	75.73	3	1.83
	2	7.00	3	0.39
Plying on the Missouri river, above Yankton	9	2,169.44	17	85.26
	1	72.18	1	5.58
	1	19.09	2	3.93
Plying from New Orleans and Vicksburg inland, unspecified	11	15,610.81	22	1,130.13
	10	6,929.83	20	324.20
	67	16,119.81	131	728.91
	27	1,954.78	51	64.77
	23	846.07	31	49.32
	28	282.02	38	10.65
Plying from Saint Louis inland, unspecified	11	15,247.48	22	712.52
	27	19,003.67	54	1,002.23
	50	15,044.96	98	1,039.86
	11	950.10	20	82.85
	4	165.80	7	7.93
	8	65.30	10	2.90
Plying inland from Saint Paul and ports of the Upper Mississippi, as far south as Burlington, to ports unspecified.	36	7,221.51	72	422.06
	23	1,628.94	41	77.27
	14	507.23	26	26.29
	10	179.40	13	5.63
Plying from Pittsburg and Wheeling inland, to ports unspecified.	1	1,034.15	2	25.72
	18	12,117.93	36	1,008.55
	97	21,838.04	194	2,095.35
	15	1,129.75	29	102.09
	6	257.68	9	18.07
	8	114.39	12	6.83
Plying inland from Louisville, Cincinnati, Evansville, Owensborough, and Metropolis.	16	11,178.16	32	523.56
	20	6,786.13	58	332.59
	26	1,981.65	43	76.19
	6	252.73	7	5.85
	7	111.39	11	8.62
Plying from Memphis and Cairo inland, unspecified	2	1,586.18	4	110.71
	14	4,517.51	28	182.19
	6	451.52	10	20.93
	4	165.85	6	5.96
	6	83.67	7	6.05

After the numbers of engines are specified their aggregate volumes in cubic feet. This is a better indication of the relative powers for stern-wheel engines, such as the majority of the foregoing, than for propeller engines.

ENGINES OF MISSISSIPPI RIVER STEAMERS.

Of steamers of over 1,000 tons, there are the following thirty-three, of which the following list is given in full with the kinds and dimensions of engines, which, unless specified, are simple non-condensing engines: the "J. B. M. Kehloe," 2,293.73 tons, has two, 18″ and 44″ by 6′ compound engines.

Engines, simple non-condensing.

Name.	Tons.	ENGINES.		Name.	Tons.	ENGINES.	
		No.	Dimensions.			No.	Dimensions.
Thos. Sherlock	1,353.02	2	24″ by 8′	Chas. P. Chouteau	1,304.12	2	22″ by 8′
R. R. Springer	1,215.35	2	24″ by 8′	W. P. Halliday	1,375.40	2	24½″ by 10′
Fred. A. Blanks	1,200.84	2	26″ by 9′	Commonwealth	1,105.05	2	22″ by 9′
Charles Morgan	1,224.26	2	28″ by 8′	Centennial	1,077.49	2	26″ by 7′
Guiding Star	1,121.97	2	22¾″ by 7½′	City of Helena	1,058.28	2	26″ by 8′
United States	1,083.92	2	26″ by 10′	Grand Tower	1,058.28	2	26″ by 8′
Genl. Lytle	1,053.25	2	26″ by 9′	Ed. Richardson	2,048.34	2	38″ by 10′
Fleetwood	1,036.60	2	26½″ by 8½′	J. M. White	2,027.76	2	43″ by 11′
Will Kyle	1,017.25	2	22″ by 7′	Thompson Dean	1,564.38	2	30″ by 10′
Wyoming	1,034.15	2	18″ by 7′	Robert E. Lee	1,479.10	2	40½″ by 10′
Henry Frank	1,169.64	2	28¾″ by 9′	Natchez	1,477.27	2	34″ by 10′
City of Vicksburg	1,058.28	2	25″ by 8′	Robt. Mitchell	1,219.81	2	22¾″ by 8′
James Howard	2,321.44	2	34″ by 10′	Annie P. Silver	1,199.52	2	22″ by 8′
John A. Scudder	1,747.22	2	28″ by 8′	New Mary Houston	1,163.93	2	22½″ by 7′
City of Alton	1,458.33	2	30″ by 9′	John W. Cannon	1,144.34	2	34⅛″ by 9′
City of Greenville	1,438.06	2	26″ by 10′	U. P. Schenck	1,086.72	2	21″ by 7′

This includes only the characteristic river boats, passenger-steamers, many of them of high speed, such as the "J. M. White" and "Guiding Star." All of the swift passenger-boats have side-wheels, all of the stern-wheel boats being of slow speed, although some are used in and equipped for passenger service. We see that there is scarcely an exception to the usual type of paired simple long-stroke non-condensing engines. "The condensing-engine has been used on the "James Howard," but when the condenser was in use a double force of firemen had great difficulty in maintaining the steam-pressure" (Bryant). The "Wyoming" is an example of a stern-wheel boat, but there is no usual or distinguishing difference in the proportions of engines between stern- and side-wheel boats. High powers are realized for the proportions on account of the profligate use of steam, the terminal pressures being great enough for the initial pressures of ordinary high-pressure engines. Engines which throw away three or four tons of fuel where they utilize one are certainly subjects for future improvement. Condensers would certainly be a great improvement upon such practice, even if the vacuum was poor; but with such high-pressures and proper expansion the power of the steam could be as fully realized without as with the use of condensers. With proper expansion, condensers would be found an adjunct entirely undesirable for high-pressure river engines, not only involving increased first cost but a positive detriment to economy. To admit 170 pounds steam into a long-stroke cylinder chilled by connection with a condenser is to seriously lower the mean effective pressure.

Special surface-heaters are commonly used and the feed is heated nearly to boiling point, while upon ocean steamers 120° is a common temperature of feed. Comparing the feeding capacity of the engines of the "Ed. Richardson" with those of an ocean steamer (compound):

Class.	Tonnage.	Feed pumps.	Passed per revolution.		Ratio.	Boiler-pressure.
			Cylinder volume.	Pump volume.		
			Cubic feet.	*Cubic feet.*		*Pounds.*
River steamers	2,048.34	1—7½″ by 26″	314.72	0.665	.0021	173
Ocean steamers	3,019.56	2—6″ by 24″	564.19	0.784	.0013	73

Although these river engines are of long stroke, the actual length of stroke is seen to range considerably below that of the beam-engines upon the Hudson river and Long Island sound. The side-wheel boat "J. M. White," probably the swiftest on the Mississippi, has exceptionally large cylinders, the cubic volume being about 222 cubic feet.

Upon steamers of Class II the engines are of precisely the same type as in the preceding class, and invariably paired. A steamer driven by a single cylinder engine is unknown among these large vessels.

In this class most of the steamers are of the stern-wheel type, which is much more common than any other type. This class also includes the largest towing-boats. Of 188 engines in this class 180 are of the simple non-condensing type and 8 are of the Hartupee compound-moderator type.

COMPOUND ENGINES.

Name.	Tons.	Engines.	
		No.	Dimensions.
E. O. Stanard	824.51	2	12″ and 26″ by 5′
Mollie Moore	601.70	2	12″ and 26″ by 5′
John A. Wood	687.52	2	18″ and 41″ by 8′
Joseph B. Williams	801.91	2	19½″ and 41½″ by 9′

The two former are inspected as passenger-steamers and the two latter as tow-boats. The "E. O. Stanard" and the "Mollie Moore" are specified as plying from Saint Louis inland; the "John A. Wood" and the "Joseph B. Williams" from Pittsburg inland. The latter are the most powerful towing-boats upon the river, the aggregate cylinder capacity of their engines being 5 or 10 times as great as that of other boats of this class. But in illustration of their greater economy of fuel it should be noted that relatively small boiler capacities are required.

The "Belle of Memphis," 919.69 tons, has 2 simple engines, 26″ by 8′, volume 59.96 cubic feet, 5 four-flue boilers, 44″ by 26′, volume about 1,372 cubic feet. The "Oakland," 628.81 tons, has 2 simple engines, 26″ by 9′, volume 66.32 cubic feet, six-flue boilers, 40″ by 30′, volume about 1,568 cubic feet. The "Joseph B. Williams" has six-flue boilers, 40″ by 28′, volume about 1,463 cubic feet. The "John A. Wood" has six-flue boilers, 40″ by 26′, volume about 1,359 cubic feet.

The boiler-pressures allowed are: for the "Belle of Memphis" 131 pounds, "Oakland" 150 pounds, "Joseph B. Williams" 174 pounds, and "John A. Wood" 150 pounds. The boiler-volumes are 6.94 times the cylinder-volumes for the compound condensing and 23.28 times the cylinder-volumes for the simple non-condensing engines.

The tow-boat "John Dippold," 554.97 tons, with two 24″ by 8′ engines, has boilers of precisely the same size as those of the "Joseph B. Williams," pressure 140 pounds; but the cylinder-volume of the "John Dippold" is less than one-fourth that of the "Joseph B. Williams." None of these engines exceed 9′ in stroke, and the cylinders of the simple engines seldom exceed 26″ in diameter for this class of steamers.

The non-condensing engine is the all but universal type; but the "Bonanza," 776.38 tons, a passenger-steamer plying between Cincinnati and Marietta, has two 22⅜″ by 7½′ simple condensing-engines.

In steamers of Class III we begin to find a few variations from the prevailing types of engines and boilers, but they constitute a very small minority. Plying from New Orleans to the sea and inland are a few screw-propellers with return-tubular boilers, and in the upper Ohio district there are quite a number of slide-valve engines, in place of the usual poppet-valve engines. But apart from these New Orleans boats running to the sea, there are no screw-propellers of considerable size upon the Mississippi or its tributaries. These New Orleans boats have return-tubular boilers and in some cases condensers, but tubular boilers and condensers are of very rare occurrence upon Mississippi river steamers.

In this class, in the Pittsburg, Evansville, and Nashville districts, every boat is driven by paired engines. In the Saint Louis district 21 out of 90, in the Galena district 2 out of 73, in the Memphis district 2 out of 31, in the Louisville district 2 out of 29, and in the Cincinnati district 1 out of 50 steamers are driven by single engines.

In the Saint Louis district, in this class there are 6 out of 159 Hartupee compound engines, the rest being simple non-condensing. The "Katie P. Kountz," 468.25 tons, has two 10″ and 23″ by 4½′ Hartupee engines. The "Henry C. Yager," 373.44 tons, has two 23″ and 45″ by 6′ engines. The "General Meade," 171.46 tons, has two 8¾″ and 23″ by 4′ engines. The last-named boat plies from Omaha inland. All of the Hartupee engines are upon boats built between 1870 and 1878, and no compound engines appear to have been since applied in the Mississippi service.

The ferry-boat "Denver," of Bismarck, Dakota, has one 22″ by 7′ engine. The ferry-boat "Lyons," city of Lyons, Iowa, has one 18⅝″ by 5′ engine. Nearly all of the single engines are upon side-wheel ferry-boats. The passenger-steamer "Henry Logan," 111.21 tons, plying between Cincinnati and Parkersburg, West Virginia, has two 9″ by 3′ condensing-engines. The "Rapid Transit," 111.29 tons, a passenger-steamer plying between Cincinnati and New Orleans, is one of the largest screw-propellers plying upon the Ohio river, and has four 12″ by 10″ non-condensing engines. In the Wheeling district an entirely exceptional type is presented in the paddle-wheel steamer "Little Boone," 137.66 tons, plying from Gallipolis to points on the Kanawha river. This boat has two 8″ by 16″ oscillating engines and a 44″ by 10′ marine boiler. The slide-valve engines, of which there are a considerable number upon Wheeling steamers of this class, are long stroke engines, driving paddle-wheels, and are modifications of the usual practice with land engines. Most of them are tow-boat engines. The "Bell Prince," 109.12 tons, is a tow-boat, with 2 slide-valve engines 12½″ by 4½′, and 2 double-flue boilers 38″ by 24′. It is stated to consume 500 tons of coal in running from Wheeling to Pittsburg and return, towing an ordinary load.

The ferry-boat "Porter," 280.35 tons, of New Orleans, is a screw-propeller with four 16″ by 16″ condensing-engines and two 6′ by 15′ fire-box cylindrical tubular return boilers. The pressure allowed is only 45 pounds. The screw-propeller "Martha," 175.11 tons, with one 32″ by 32″ condensing-engine and a fire-box return-tubular boiler

(allowed 30 pounds pressure), plies from New Orleans inland. The more usual type of boat plying inland from New Orleans may be exemplified in the steamer "Jewel," 237.92 tons, which has two $12\frac{1}{4}''$ by $5'$ non-condensing engines and two $40''$ by $26'$ return-flue boilers of steel, and allowed 181 pounds pressure. The "Jewel" has a $3\frac{1}{4}''$ by $11''$ feed-pump single-acting; the feed is heated to 180° Fahr., and the safety-valve area for the boilers is 25.13 square inches.

Steamers of Class IV are propelled in the majority of cases by stern wheels, but there are a great many screw-propellers, especially among the tug-boats. Freight- and passenger-boats have more commonly stern wheels. Simple short-stroke non-condensing engines are used upon the propellers. These have slide-valves in most cases, while the paddle-wheel engines have poppet-valves, but not without occasional exceptions. The paddle-wheel steamer "Georgie Lee," 91.19 tons, of Saint Louis, has two $9''$ by $3'$ engines with slide-valves, and in some districts, notably that of Wheeling, they are quite commonly met with. Mr. W. H. Bryant states that slide-valves were formerly much in use, but that they have been abandoned for the poppet-valve on all but small boats. The objections to the slide-valve are stated to be unreliability under high pressures, failure to open as promptly and sharply as desired, and, as usually built for river engines, excessive clearance. While these objections might doubtless be overcome by suitable designs and valve-gears and good workmanship, the poppet-valve is admitted to be better for long-stroke engines, and in spite of predictions to the contrary, we find the poppet-valve achieving a high success, even in engines for screw propulsion. There are no more creditable nor original examples of American ocean-going practice than the poppet-valve engines of the "Hudson" and the "Louisiana," but here upon the rivers the poppet-valve has a peculiar province and will probably never be displaced.

With propeller-engines, as we pass from large to small, the piston-speed is very nearly maintained, the number of revolutions increasing as the stroke shortens, but with paddle-wheel engines the speed of revolution is limited and the small engines for stern-wheel boats are slow both in piston and rotative speed. The evils peculiar to any type of valve are therefore minimized, and either poppet- or slide-valves fulfill every requirement. Some of the small paddle-wheel boats are driven by very short-stroke engines. Thus the tug-boat "Gopher," 59.88 tons, of Saint Paul, has one $10''$ by $12''$ engine, but a more usual type may be exemplified by the steamer "Last Chance," 50.47 tons, which has two $10\frac{1}{4}''$ by $3\frac{1}{2}'$ engines. The "M. T. Powell," plying from Little Rock, Arkansas, has two $6''$ by $2'$ engines. The "Rose City," 80.69 tons, plying on Red river, has two $8''$ by $2\frac{1}{2}'$ engines. The "Athletic," 81.76 tons, plying on the Monongahela river, has two $12\frac{1}{4}''$ by $4'$ engines. In every section of the great valley we find the same types with but little variation. In the Wheeling district we find side by side engines of the same dimensions, some with slide- and some with poppet-valves. The paddle-wheel passenger-steamer "Luella," 50.50 tons, of Gallipolis, has two $9\frac{1}{8}''$ by $3'$ engines with rotary-valves. The "Sylvan Dell," 53.08 tons, a small screw-steamer, plying inland from New Orleans, has four $12''$ by $8''$ engines. This as usual has non-condensing engines, but it has tubular heaters which raise the feed to 180°, although the boiler-pressure allowed is only 90 pounds. The feed-heaters are important adjuncts to the river engines. The "Sylvan Dell," with four $12''$ by $8''$ engines, aggregating about 2.1 cubic feet cylinder volume, has one $3''$ by $6''$ feed-pump, about .007 of the capacity of the cylinders per revolution.

The same types of engines are found upon the steamers of Classes V and VI. There are no compound engines in these classes, and condensing-engines are the very rare exception. The "S. C. Hall," plying from New Orleans to the sea and inland, has a $20''$ by $22''$ condensing-engine.

ENGINES OF THE MONTANA.

There are two engines with cylinders $18''$ in diameter by $7'$ stroke, of cast-iron, $1''$ thick at the thinnest point. The engines are right- and left-handed, but otherwise similar. They are placed at the inclination of about 6° from the horizontal. The valves are poppet, two steam-valves on one side of the engine and two exhaust-valves on the other side. The valve-stems are lifted and lowered by arms pivoted beyond the ends of the cylinder and extending to the middle, where they nearly meet, a pair of these levers on each side of the cylinder, and under them a pair of wipers or lifters upon a rock-shaft. These lifters have toes of equal length, and the rock-shaft being over the middle of the cylinder, and the lifters set at an angle with each other, they may be so arranged that two valves will be continuously open, first the steam-valve at one end and the exhaust at the other, and then the reverse alternately. This is accomplished by giving the rock-shaft a motion from what is called a full-stroke cam, a cam of two curves working within a rectangular frame, which incloses the main shaft, and is itself suitably supported in slide-bearings. If now we connect the lifters on one side (the steam-valve side) with a cam having a shorter throw, the valves would close sooner and cut off, giving the advantage of expansion of the steam, but, in order that the valves may open properly, it is necessary to use a different cam, namely: one with three points and three curves and four positive motions, where the full-stroke cam has but two. This, instead of admitting steam for half a revolution, admits it for a quarter or more of the revolution, while the full-stroke cam continues to operate the exhaust-valves as before. Such is the operation of the poppet-valve gear of a western river engine. In starting or reversing, or when full power is required, the full-stroke cam rocks both lifters and operates all four valves, but when under way the steam-lifter is connected with a new cam which operates as described. An endeavor has been made to illustrate

this action by the skeleton sketch of Fig. 31. This shows the crank and the two cams. Only the valves on the steam side are shown, the others being behind them. A is the cut-off rod shown as lifting the exhaust-valve on the right-hand side. The piston is at the beginning of its stroke and the three-pointed cam is about to throw up the left-hand toe of the nearer lifter (the steam-lifter), and to lift the steam-valve at that end. The engine is of very long stroke, and to save space the connecting-rods are shown broken, but the actual relative sizes of the parts are shown by a sketch to a smaller scale. In another illustration (Fig. 32) the cylinder is shown with its valve connections in three views of two sections through the valves. The cut-off cam is shown in the same figure. The

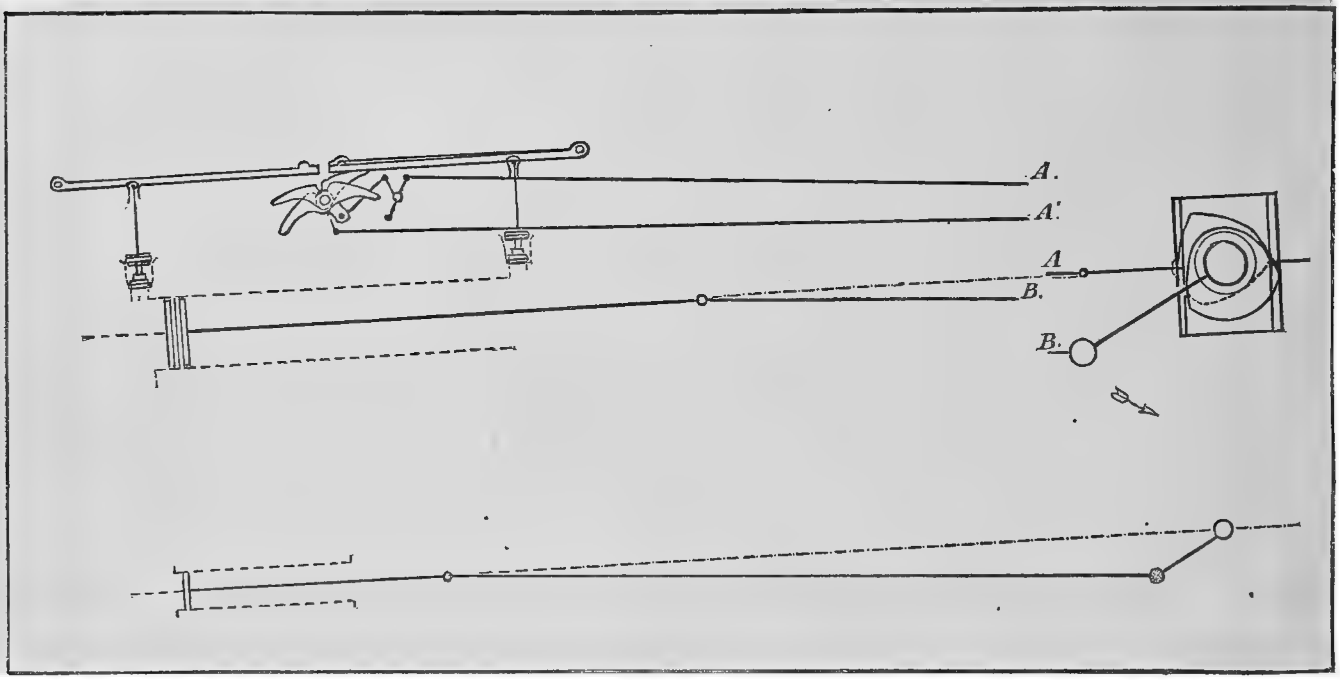


FIG. 31.

main cranks overhang outside the frame which supports the stern-wheel, and the cams are upon the crank-shaft within the frame. The connecting-rod is of wood of a cruciform section. It is strengthened by iron bands at top and under side bolted together. The cross-head journal is not strapped and keyed upon the rod on the connecting-rod side, but the iron bands of the rod extend over the journal-boxes and are keyed together on the further side. The piston-rod extends into a socket of the cross head, to which it is fastened by a single large key. It is also keyed to the piston, which has two $\frac{3}{4}''$ copper rings, lined by a $\frac{1}{4}''$ iron ring held out by elliptic springs secured by set screws. The rings are kept in place by a follower bolted on with square-headed bolts. The piston and follower are of cast-iron.

The distance between the center lines of the two engines of the "Montana" is 40′.5, the cranks are at right angles and the connecting rods are 30′ long. The timbers which support the frame extend 18′.4 beyond the after end of the hull forming the support of the main journals and the stern-wheel and supported in turn by a system of hog-chain bracing.

	Cubic feet.
Effective volume of cylinder	12.375
Volume of clearance at one end	.8343
Total	13.2093

Clearance, per cent. of entire volume, 6.3.

The valves are double and balanced. Of the steam-valves the upper poppet is 5″ and the lower one $4\frac{1}{2}''$ in diameter. Of the exhaust-valves the upper poppet is $4\frac{1}{2}''$ and the lower one 5″ in diameter. The valve arms or levers are of cast-iron 5′ 3″ long, 1″ thick, and 4″ wide. There is a 9-pound weight on each lever and the valves are kept well seated by an effective pressure of 132 pounds at the valve-stems. The two lifters, steam and exhaust, work upon the same shaft but independently of each other.

The piston-rod is of wrought-iron and 4″ in diameter. The cross-head is of cast-iron, with the pin cast in. The guides are flat 3″ by 2″ and 7′ 6″ long. They are embraced by jaws attached to the cross-head. The iron straps of the connecting rod are $3\frac{1}{2}''$ wide by $\frac{1}{2}''$ thick. The sectional area of the wood is about 50 square inches at the ends and about a square foot in the middle of the rod. The crank tapers from $8\frac{1}{2}''$ to $4\frac{1}{2}''$ thick. It is shrunk upon the shaft and also upon the crank-pin. The cams are of cast-iron, made in halves and bolted to a collar forging on the main shaft.

Stern wheels have longer buckets than side wheels, but are usually of a less diameter. The wheel of the "Montana" is of wood (the usual material). It is 35′ wide on shaft, and its diameter is 16′ center to center of buckets and 19′ over all. There are 7 sets of wheel-arms, each with 13 arms, braced together by cross-pieces. The

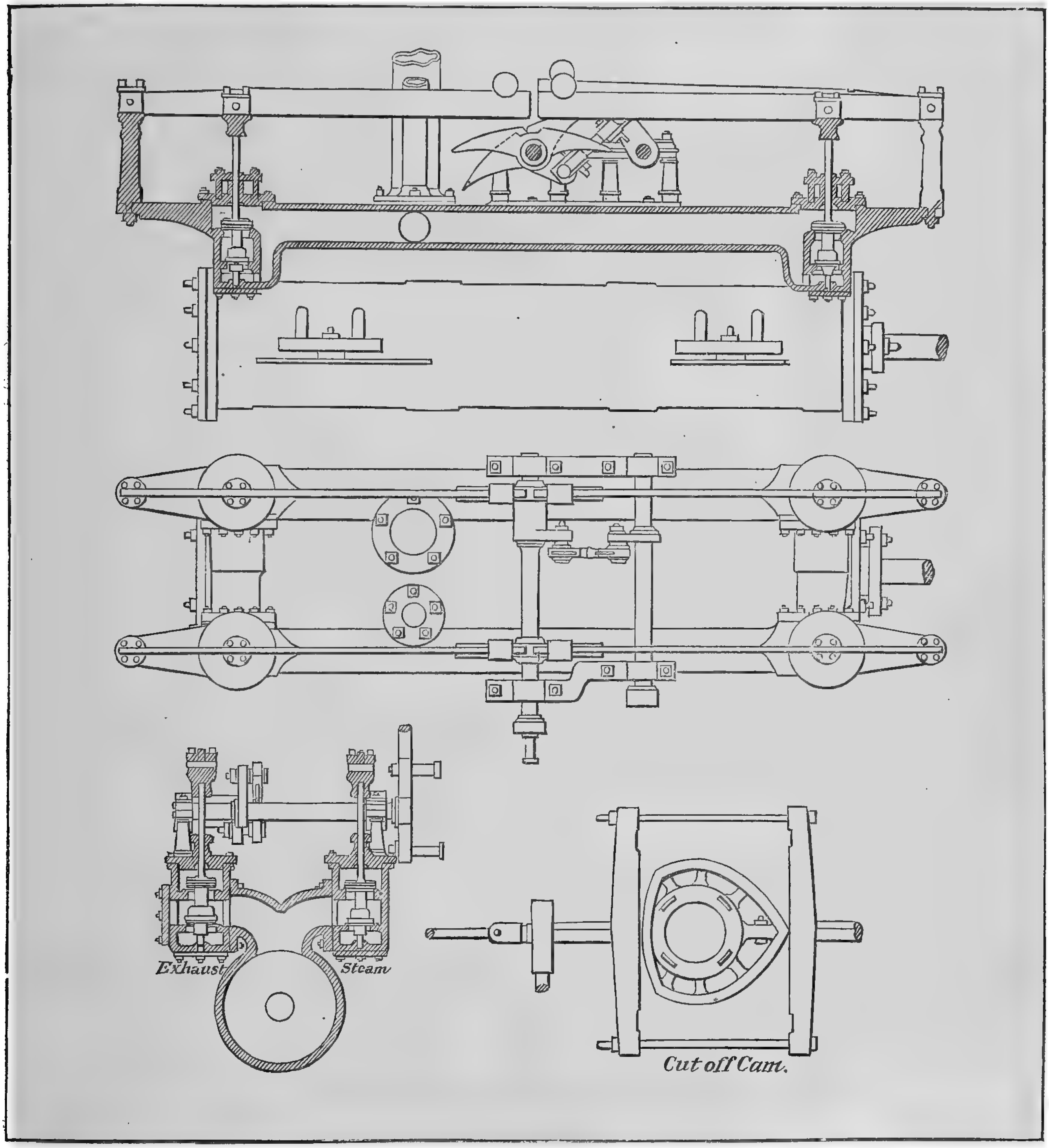


Fig. 32.

main shaft is cylindrical throughout, of wrought-iron, 40′ long, $10\frac{1}{4}''$ in diameter, and weighing 44,026 pounds. For each set of wheel-arms there is a 44″ (diameter) flange, 1″ and 2″ thick, and let into the arms. The buckets are oak planks bolted to the arms and extending the width of the wheel. The cranks are balanced by pine beams extending the entire width of the wheel.

The above details regarding the steamer "Montana" are mainly derived from a paper by Mr. W. H. Bryant, of Saint Louis, this paper being the most complete and comprehensive description of the western river stern-wheel boats which has yet been published.

The "Montana" makes, at the highest, 25 revolutions, and commonly 18 or 19 or less, per minute, the piston speed at 19 being 266′ a minute. She is allowed 140 pounds pressure in her boilers, and, having 2 cylinders of 18″ diameter, would have a nominal horse-power of about 248, based on a mean pressure of half the boiler-pressure and a piston speed of 230′, or about $16\frac{1}{2}$ revolutions per minute. The admission as usual for these steamers ranges from $\frac{1}{2}$ to $\frac{7}{8}$ of the stroke when cut off at all, and, as some of these western river engines *discharge* their steam at half boiler-pressure, it is obvious that a much higher power is realized than appears in the nominal rating.

The slow rotative speed of these river-engines makes them easy to handle, and the engines are as usual governed by the movement of the boat.

Of the forms of poppet-valve used, the balanced valve is deservedly the most popular. The relief valve, in which a small valve opens first and relieves the pressure upon the principal valve, is also in extensive use, but the single valve, which with the high boiler-pressures used requires from a ton to a ton and a half to lift a 4″ or 5″ valve, is going into disuse. The great strain brought by such valves upon their actuating mechanism needs scarcely to be remarked. The balanced valves are sometimes made with poppets of equal area and sometimes, as in the "Montana's" engines, with a slight difference of area to assist in the seating of the valve.

Eccentrics are not commonly used on river engines, not giving as quick a movement of the valves as the cams. The Rees cut-off requires only one cam, the cut-off being connected with the cross-head and variable while the engine is in motion.

ENGINES OF THE "JOSEPH B. WILLIAMS" AND OTHER STEAMERS.

The "Joseph B. Williams," in common with a few other steamers, contains a form of engine much more elaborate than the usual type. This in the present river practice constitutes an objection to it, the ordinary single cylinder-engine being considered better adapted to the character of the service, but as a type of engine entirely unique and the principal application of the compound principle in Mississippi river service the Hartupee engine merits consideration. The principal features of the engine are exhibited in an illustration (Fig. 33) showing it in plan and elevation. This has previously appeared in the *London Engineer.* There are compound engines with a receiver called a moderator, in which the pressure of the steam is reduced before passing into the large cylinder. Steam enters the high-pressure steam-chest through the pipe marked "to boiler." The high-pressure cylinder has the usual form of poppet-valves and lifters actuating levers, but the cut-off is regulated by a link. The steam passes from the exhaust of the small cylinder, as shown, to the moderator and steam-chests of the large cylinder, which has four poppet-valves actuated directly by rock-shafts without the intervention of lifting levers. The arrangement of the exhaust from the large cylinder is shown in a separate figure, the feed being heated from the exhaust before passing to the condenser. The air-pump is independent and operated by a separate engine, which is a beam-engine. This also works the feed-pump. It will be seen from the illustration that the large main cylinder has two piston-rods, one passing on each side of the small cylinder. The size of the large cylinder relatively to the small is greater than usual in compound engines. Where the ratio of piston areas is usually 4 to 1 or less, it is here nearly 6 to 1. The dimensions of cylinders are:

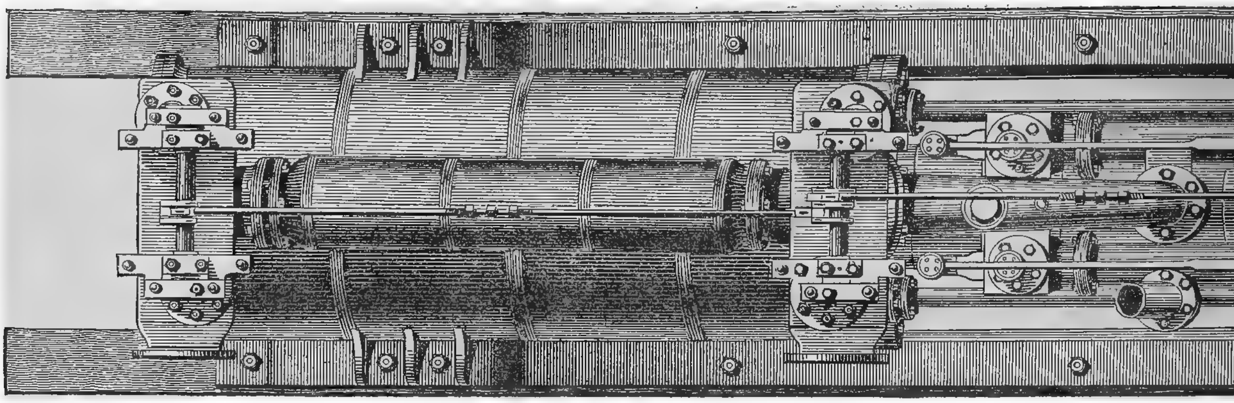
	Diameter.	Stroke.
	Inches.	*Feet.*
High pressure	19	[illegible]
Low pressure..............	44	9

The stern-wheel of the vessel is 29′ in diameter and 29′ across, with buckets 38″ deep, hung on a hexagonal shaft 35′ long with journals 15″ in diameter. The cranks are of wrought-iron keyed upon the shaft. The weight of the shaft is 25 tons.

Side- like stern-wheel boats are almost invariably driven by direct-acting inclined engines, and some of the side-wheel boats are very swift. The "Guiding Star" has made 17 miles an hour with 1,400 tons of cargo, and the "T. M. White" is even swifter. And while the stern-wheels are almost peculiar to western waters, the stern-wheel boats outnumbering the side-wheel boats about 3 to 1 on the Ohio, the inclined engines have in some cases displaced beam-engines in steamers on the Atlantic seaboard, notably in the ferry-boats of East Boston and Brooklyn, whose engines were designed by Mr. Charles W. Copeland.

In the West we find the regular steamboat poppet-valve engines sometimes used on land for manufacturing purposes. The engines used on small boats are commonly adaptations of the land engines of the ordinary slide-valve type with a change of valves, the poppet cut-off being usually put upon the steamboat engines. Corliss or rotary valves are not used, except in one or two cases of small boats having engines with rotary valves.

While the stern-wheel boats are not used on the Atlantic seaboard of the United States, they have been built there for South American rivers. Such a boat was the steamer "Tolima," built by Messrs. Pusey & Jones, of Wilmington, to ply upon the Magdalena river, New Grenada. This had two 13″ diameter by 5′ stroke simple non-condensing engines, with independent feed-pumps.



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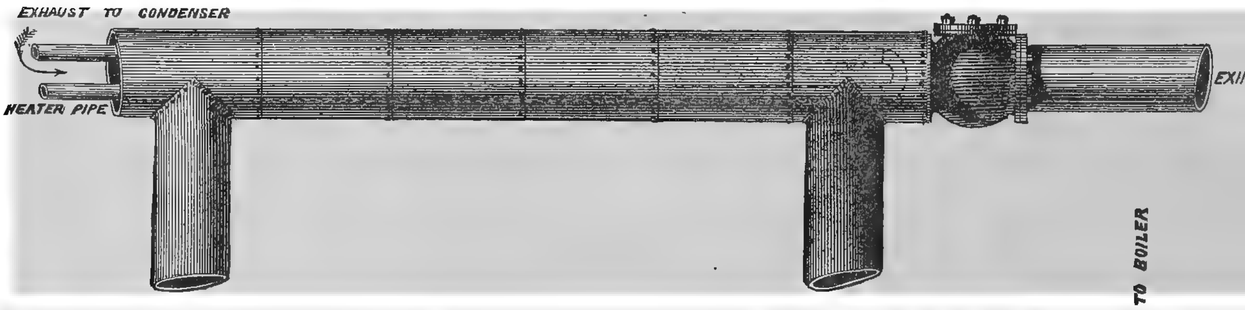
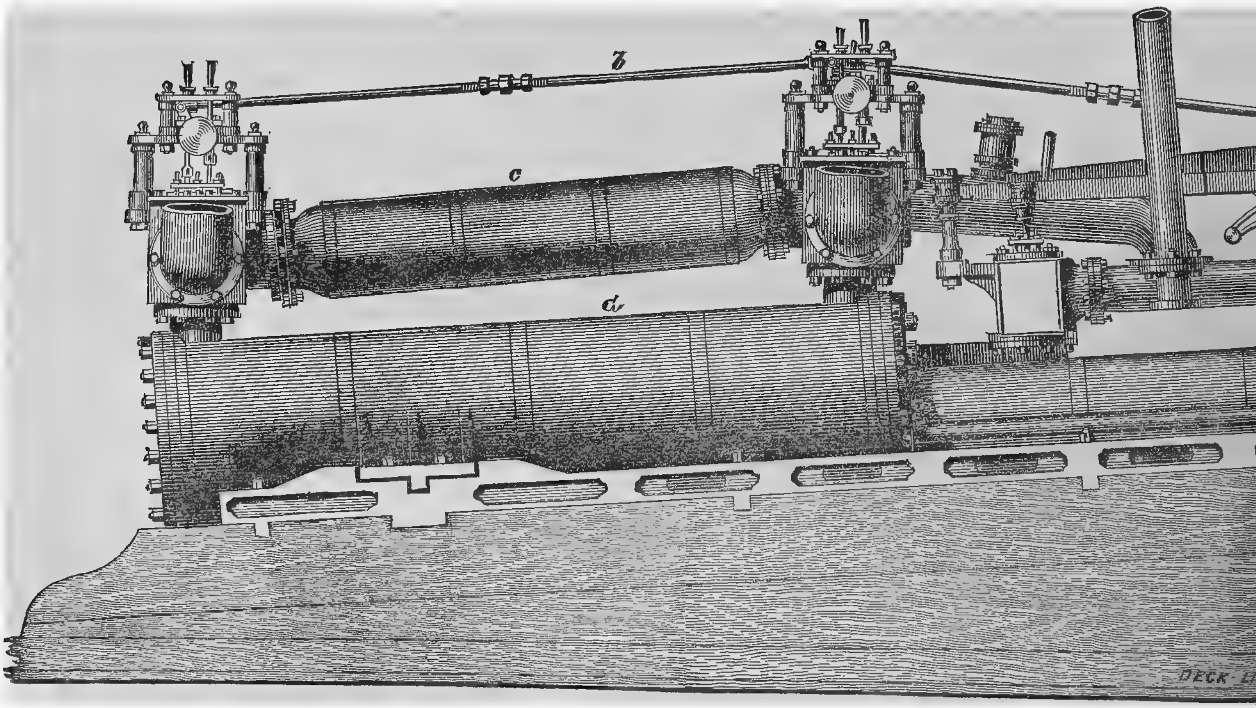
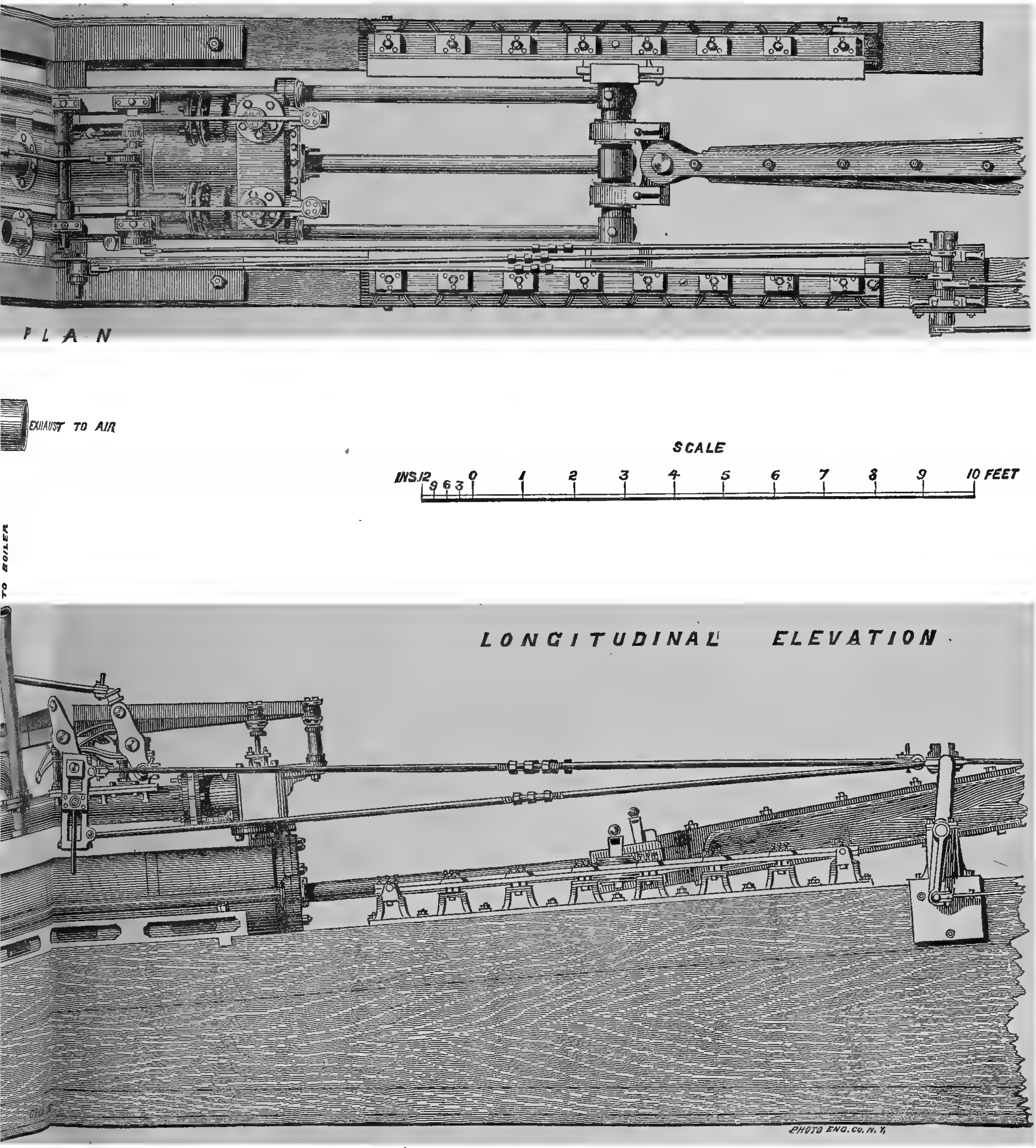





PLAN
EXHAUST TO AIR
SCALE
INS.12 9 6 3 0 1 2 3 4 5 6 7 8 9 10 FEET
TO BOILER
LONGITUDINAL ELEVATION
PHOTO ENG. CO. N.Y.

G. 33.

BOILERS OF MISSISSIPPI STEAMERS.

Upon river steamers of over 1,000 tons flue-boilers of small diameter and great length are invariably used. The following examples are given, name of steamer, number, material, and dimensions of boiler, and maximum pressure allowed:

Name.	No.	Dimensions.	Material.	Pressure.	Name.	No.	Dimensions.	Material.	Pressure.
				Pounds.					*Pounds.*
J. B. M. Kehloe	4	38″ by 24′	Iron	150	Chas. P. Chouteau	4	42″ by 32′	Steel	145
Thos. Sherlock	5	40″ by 28′	Iron and steel	156	W. P. Halliday	5	42″ by 30′	...do	173
R. R. Springer	6	40″ by 30′	Iron	156	Commonwealth	6	37″ by 28′	Iron	150
Fred. A. Blanks	6	42″ by 30′	Steel	173	Centennial	4	42″ by 22′	...do	120
Chas. Morgan	6	40″ by 28′	Iron	141	City of Helena	5	44″ by 26′	...do	122
Guiding Star	5	42″ by 28′	...do	170	Grand Tower	5	44″ by 26′	...do	123
United States	7	38″ by 26′	...do	146	Ed. Richardson	9	42″ by 32′	Steel	173
Gen. Lytle	7	37″ by 24′	...do	135	J. M. White	10	42″ by 34′	Iron	
Fleetwood	4	47″ by 30′	Steel	154	Thompson Dean	7	37″ by 30′	...do	150
Will Kyle	4	42″ by 30′	...do	173	Robert E. Lee	9	42″ by 32′	...do	163
Wyoming	4	42″ by 26′	Iron	140	Natchez	8	43″ by 36′	Steel	169
Henry Frank	1	42″ by 28′	Steel	134	Robt. Mitchell	4	40″ by 28′	Iron	139
City of Vicksburg	1	44″ by 26′	Iron	123	Annie P. Silver	4	42″ by 32′	Steel	174
James Howard	6	46″ by 30′	...do	117	New Mary Houston	1	42″ by 30′	Iron	143
John A. Scudder	6	40″ by 26′	...do	125	John W. Cannon	7	42″ by 34′	Steel	173
City of Alton	5	44″ by 28′	...do	130	U. P. Schenck	3	42″ by 30′	Iron	148
City of Greenville	5	42″ by 32′	Steel	173					

The two-flued type of boiler is the most usual form, but some have a greater number of flues, the "City of Helena," for example, having four-flued boilers. The usual thickness of material is $\frac{1}{4}''$, although some of the above boilers are of $\frac{3}{10}''$ iron. Of the boilers enumerated above, 62 out of 173 are entirely or partly of steel.

In steamers of Class II we find the same types of boilers. The diameters in many cases are no smaller, and the reduced size is obtained by using shorter boilers, 24′ and 26′ being common lengths.

In Class II, 111 out of 372 boilers are of steel. Most of the boilers have two flues, but there are many four-flue boilers.

EXAMPLES OF TWO-FLUE BOILERS.			EXAMPLES OF FOUR-FLUE BOILERS.		
Name of vessel.	No.	Dimensions.	Name of vessel.	No.	Dimensions.
John B. Maude	4	40″ by 26′	Belle of Memphis	5	44″ by 26′
E. O. Stanard	3	36″ by 24′	Tidal Wave	3	38″ by 22′
Belle of Shreveport	4	38″ by 24′	St. Genevieve	4	42″ by 24′
Iron Mountain	5	40″ by 28′	Colorado	3	40″ by 26′

In Class III, although there are few river boats with tubular boilers, excepting a number peculiar to the vicinity of New Orleans, there is at least some tendency in this direction, flues being in some instances more numerous and smaller. The few ferry-boats with single engines have, as a rule, short boilers, no more than 16′ or 18′ long. The following are examples of five-flue boilers in the Saint Louis district:

Name.	No.	Dimensions.
Belle of La Crosse	3	40″ by 26′
Spread Eagle	2	38″ by 20′
East St. Louis	3	46″ by 20′
Helene Schulenburg	2	42″ by 26′

The flues vary from 8″ to 12″ in diameter. For two-flue boilers the effective heating-surface in square feet is about equal to the boiler-volume in cubic feet including the flues, and the total heating-surface is about 40 per cent. more. For five-tube boilers of 40″ to 46″ in diameter, and 18′ to 26′ long, the number of square feet total heating-surface is between 1.7 and 1.8 times the number of cubic feet total volume.

Some boilers on this class of steamers have more than five flues. The "Thos. D. Fits," of Nashville, has two 40″ by 18′ boilers, each with nine 6″ flues. The "Selkirk," 119.08 tons, of the Galena district, has two 44″ by 14′ six-flue boilers, and the "Col. Macleod," 171.69 tons, has two 42″ by 22′ ten-flue boilers. The "Aunt Betsy," 160.61 tons, a passenger-steamer of Saint Paul, Minnesota, has one 62″ by 18′ locomotive tubular boiler, but this is exceptional. The "Kitty Nye," 121.94 tons, plying inland from New Orleans, has a 48″ by $18\frac{1}{2}'$ locomotive-boiler in which the pressure allowed is 115 pounds. There seems to be no insuperable obstacle to the use of tubular

boilers on these river steamers as they are used in similar service on the Pacific coast, but the flue-boilers seem particularly adapted to a low grade of fuel, a low grade of water, and a low grade of management, and have thus maintained their uncontested popularity.

Of steel boilers in river steamers of this class the following enumeration is made: Saint Louis district, 34 out of 239; Galena district, 20 out of 147; Nashville district, 2 out of 22; Memphis district, 21 out of 70; Evansville district, 8 out of 41; Louisville district, 22 out of 77; Pittsburg district, 88 out of 28[illegible]; Cincinnati district, 38 out of 130; Wheeling district, 21 out of 88; New Orleans district, 32 out of 161, exclusive of boilers of coasting steamers.

Upon steamers of Class IV, flue-boilers with 2 or 4 flues make up the great majority, but there are many multi-flue and tubular boilers, although scarcely any vertical. The "Jacob Tamm," 92.36 tons, of Saint Louis, has one 48″ by 18′ 12-flue boiler, and the "John L. Ferguson," 79.81 tons, of Saint Charles, Missouri, has one 42″ by 16′ boiler with 12 tubes. The ferry-boat "S. C. Clubb," 52.69 tons, plying between Saint Louis and East Saint Louis, has two 14-flue boilers 42″ by 16′. The ferry-boat "Rescue," 57.79 tons, of Saint Louis, has one 58″ by 18′ boiler with 39 tubes. The passenger-steamer "Pete Wilson," 69.36 tons, of Dubuque, has one locomotive-boiler 36″ by 8′. The "Pete Wilson" is a paddle-wheel boat with a 10″ by 12″ engine, but the "S. C. Clubb" and the "Rescue" are screw-propellers. The passenger-boat "Philip Sheckel," of Reed's Landing, Minnesota, has a 42″ by 10′ boiler, with water back and sides.

Many of the smaller boilers have fire-boxes. In this class in Memphis district 7 out of 26 boilers are specified as having fire-box boilers. The larger river boilers do not have fire-boxes. The usual method of setting with brick-work, and in many respects like the setting of stationary boilers, will be elsewhere illustrated. The "Madison," 53.21 tons, of Louisville, Kentucky, has one 36″ by $9\frac{1}{2}$′ fire-box tubular boiler. Pressures continue high in these small boilers, but the average is less than in the larger sizes, quite the reverse of the case upon the Atlantic seaboard. The paddle-wheel boat "Katy Did," 84.61 tons, of Little Rock, Arkansas, has a coil-boiler or steam-generator of four concentric coils, which is allowed a pressure of 210 pounds. The paddle-wheel boat "Wild Goose," 70 tons, of Wheeling, West Virginia, has a coil-boiler which is allowed 190 pounds pressure. The "Wild Goose" has two $9\frac{1}{4}$″ by 3′ slide-valve engines, and the "Katy Did" two $11\frac{3}{4}$″ by 4′ slide-valve engines. The "Jessie," 98.46 tons, a paddle-wheel steamer plying inland from New Orleans, has one 42″ by 9′ vertical tubular boiler.

In this class about 8 per cent. of the total number are of steel, and in Classes V and VI there are few steel boilers. The boilers of these latter classes present few features of special interest. Where vertical tubular boilers are the prevailing type upon small steamers of the Atlantic seaboard they are the exception here. There are a great many fire-box tubular boilers, but simple two-flue boilers are found upon some of the smallest steamers. If anything, the diameters of boilers increase as we pass from the larger to the smaller steamers, for some of the smallest have boilers over 50″ in diameter, while in the list of the largest steamers previously given few will be found with boilers over 42″ in diameter.

DESCRIPTION OF RIVER-BOAT BOILERS.

The simple form of flue-boiler commonly employed on western river boats, although not the most economical of space nor furnishing the greatest amount of heating-surface, is comparatively easy to build and easy to clean. The latter is an important point in any boiler, but especially so if, as is the case on these rivers, the water is liable to contain sediment and impurities. But the feature which more than any other served to establish the plain-flue boiler in undisputed popularity is its adaptability for a low grade of fuel. Coal is now much used upon the Ohio and upon the large Mississippi river steamers, coal and wood being used in about equal quantities on the lower Missouri, while on the upper Missouri and the Yellowstone wood is the only fuel to be had. "Experience seems to show that the best results of the heating value of these fuels are obtained by mixing them in about equal quantities in the furnace."—(Bryant.) The river boilers are designed with especial reference to wood-burning, and few steamers use coal exclusively, and the abundance of fuel in some sections makes the practice wasteful.

We cannot expect the best engineering practice until necessity demands it, and even then the methods and proportions incident to wasteful practice having the force of precedent may be expected to assert themselves long after they have outlived their conditions of special usefulness. The features peculiar to boilers adapted to a low grade of fuel are such as might be suggested for a greater volume, both of fuel and products of combustion, for the same heat evolved. The grates must be large, and the fire-flues of the boiler must be large relatively to the water-spaces, for to furnish the same amount of heat a greater volume of products of combustion must pass over the heating-surface. If, however, the draught be forced, we have the same result with smaller flues. Dilute products of combustion, if we may so speak, are rapidly cooled, and low grades of fuel require relatively shorter and larger flues and larger furnaces for the same heating-surface.

The following description of the furnaces and boilers of the "Montana" (which may be taken as typical) is given in the *American Engineer* by Mr. W. H. Bryant, of Saint Louis:

In general the furnace and boilers on western river boats are placed about one-third of the boat's length from the bow. While this arrangement gives the best distribution of weight, it at the same time renders it necessary to carry the steam to the engines through a

long exposed pipe, and serious condensation may occur before the steam reaches the cylinders. This, however, can be largely reduced by properly covering the steam-pipe. To remove this difficulty altogether, and also to secure more room on the forward decks, the boilers have in some cases been placed near the after end of the boat, close to the engines themselves. This, however, gives such unequal distribution of the load upon the hull that it has not met with general approval.

The common type of furnace in use has low ash-pits, grate-surface horizontal, and from 12″ to 18″ from shell of boiler, and the flame-bed reaches from the top of the bridge-wall to the after end of the boiler, not more than for 3″ to 6″ below the shell. In the spandril between the boilers, when more than one is set in the same furnace, the combustion-chamber reaches to within a few inches of the water-line. It is lined with fire-brick only where the heat is most intense, red brick being used everywhere else. They differ from marine furnaces in being much longer, with ash-pits and long shallow combustion chambers, level grate-surface; and must often be adapted for burning particular kinds of fuel. They also differ from the usual type of stationary boilers in not having combustion-chambers as well proportioned, and, in general, using some kind of artificial draught. They differ also from the locomotive furnace in having a stationary grate near the heating-surface, return passages through boiler, large grate-surface, and high stacks.

The furnace of the "Montana" may be taken as a general type. Its detailed dimensions are as follows: The fire-box or furnace proper is 14″ high under shell, and 37″ high in spandril between boilers. It is 17′ wide (there being four boilers, 26′ long by 41″ diameter, set in one furnace), $6\frac{1}{2}$′ long to top of bridge-wall, and lined with fire-brick.

The grate is horizontal, 17′ wide by 4′ 2″ long, 70.8 square feet of grate-surface. The bars are the most common form, of cast-iron, having an inch space longitudinally in center, making each bar really two. The bars themselves are held 1″ apart by $\frac{1}{2}$″ lugs on each side, and are supported by cast-iron bearing-bars. The top of grate is 30″ above main deck and 2″ below bottom lining of fire-door.

There is no hearth- or coking-plate, nor is any part of the grate dead.

The mouth-pieces consist of doors, 18″ wide by 14″ high between the boilers, and half doors, 12″ wide by 13″ high, on the outboard side of the outboard boilers. Also a poker-door, 10″ by 5″ immediately under each boiler.

The fire-doors are of cast-iron, corresponding to the openings above named and close to them. There are two or three $\frac{1}{2}$″ holes in each door to admit air above the fuel bed.

The furnace front is of cast-iron, made in several pieces so as to fit boilers. It rests on a 6″ by 10″ wooden beam athwart decks. It supports forward end of boilers and grate, and is lined with fire-brick.

The ash-pit is the same width and length as the grate-surface, and is 18″ high to grate bars. The water of condensation from the exhaust steam in the long escape-pipe leading to smoke-stacks is run into the ash-pit to put out the live particles falling through the grate.

The ash-pit doors are of sheet-iron, and are 5 in number, 3 large and 2 small ones.

The bridge wall, immediately behind the grate, is 11′ high, reached by a slope of 2′ horizontal length. It is supported, together with the after end of the grate bars, by a special frame, and is lined with fire-brick tiles.

The bed of the flame-chamber slopes gradually back from the bridge, where it is only 3″ below the boiler-shell, to the after end of the boiler, where it is 6″ below. It consists of red brick laid in and covered by earth, the whole being about 4″ thick. It is perforated by the connections of the mud and feed-water drums from each boiler. There is a 12″ space between the after end of the boiler and the end of the flame-chamber, where the hot gases enter the flues. The side-walls are lined with common red brick.

There are no air-passages other than those through the ash-pit and fire-doors.

The flues are two, 26′ long by 15″ in diameter, in each boiler, eight in all. No bafflers are ever used, so far as we know. The smoke-box or uptake, here known as the "breeching," receives the gases from the eight flues, and extends all the way across top of boiler front. It is about 24″ wide and 2′ to 3′ high, joined at each end to the stacks.

The stacks, two in number, are of sheet-iron, not over $\frac{1}{8}$″ thick and 3′ in diameter. They are 40′ high above hurricane roof, and 55′.3 effective height above grate-surface. The weight of each stack is borne by a 2″ wrought-iron post resting on boiler-beams, and they are held in position by wrought-iron guy-rods attached at proper heights.

Blowers, or the ordinary steam-blast, are in common use to produce draught, but in general the exhaust steam is discharged into the smoke-box, or breeching, as in the locomotive. No data can be given to the economic value of the exhaust in giving additional draught, but the practical results are good.

No dampers are in use, the flue-caps and ash-pit doors answering their purpose.

THE BOILERS.

Steamboat boilers are *sui generis*, those in use on western rivers are especially so. Similar boilers, similarly placed and connected, are seldom met with elsewhere, for they are expected to stand harder strains and work under more difficult and trying circumstances than almost any other class of boilers. The type of boiler now in use answers all requirements and gets along with less attention, and is less liable to accident than any other kind yet tried on the river, hence this type is retained.

Many years ago, when knowledge of the properties of steam was dim and misty among river engineers and firemen, and very high pressures were always carried, racing was common. The disastrous results which so often followed led to the enactment of very stringent laws governing the construction of river boilers, and to a very general prejudice, both among the public and river men, against certain classes of boilers, particularly tubular and those of over 42″ diameter of shell. So general is this feeling that, so far as it is ascertainable, no boilers of these types are now in use, except on boats built and owned by the government. The great amount of sediment in the water no doubt led the closely-crowded tubular boilers to give trouble.

Through the kindness of the local inspectors at Saint Louis we are enabled to give the following outline of the principal laws governing the construction and working of river boilers:

1. Boilers must be tested at least once per year, by hydrostatic pressure; and the test applied must exceed the working-pressure allowed in the ratio of three to two.
2. Fire-line must be at least 2″ below minimum water-line.
3. Water-level must be kept not less than 4″ over flue.
4. Feed-water must be so delivered as not to injure boiler when entering it.
5. Fusible plugs must be placed in such position as to melt when water gets too low.
6. Boilers 42″ diameter and $\frac{1}{4}$″ thickness of shell may be allowed a working-pressure of 150 pounds per square inch; and this standard will be used in regulating pressures allowable on all boilers.
7. Each plate must be stamped with the number of pounds tensile strain it will bear.
8. The working-pressure allowed must not exceed one-sixth of the tensile strain of the sheets, unless the longitudinal seams are double-riveted, in which case 20 per cent. additional may be allowed.

9. The plates of boilers exposed to the action of the heat must not be over $\frac{26}{100}''$ thick.

10. The flues or tubes must have not less than 3″ clear space between and around them.

11. Steam connection joining sets of boilers must have an area of opening into each boiler of 1 square inch for every 2 square feet of effective heating-surface.

As will be noticed, these rules impose limitations on river boilers not met with on any other kind.

River boilers differ from the marine type in being of less diameter, much larger, and in using flues instead of tubes. Their cost is also smaller, being of simpler construction. They differ from the common stationary boiler in using large flues only, and in the variety of pressures in use and work done. They differ from the locomotive-boiler in having no water-space on sides of furnace, and having return-tubes.

The boilers of the "Montana" are 4 in number, of the cylindrical, two-flued type. They are 26′ long, 42″ diameter, with flues of 15″ diameter, and are connected together to form one battery. They are made of C. H. No. 1 iron, and were built by D. W. C. Carroll, of Pittsburg, Pennsylvania.

The shell is of $\frac{26}{100}''$ wrought-iron. The plates are 24″ in length, with 1″ lap at each end. Circumferentially they are single-riveted, rivets $1\frac{3}{4}''$ apart; longitudinally they are double-riveted, rivets $1\frac{3}{4}''$ apart, rows $1\frac{3}{4}''$ apart.

The ends are flat, $\frac{1}{4}''$ thick, flanged inward 3″ to join cylindrical portion, rivets $1\frac{3}{4}''$ apart.

The steam-chest or dome is horizontally cylindrical, extending across top of boilers, and is connected with each one by a 14″ leg. Its center is 16″ above top of shell, and it is 15′ long and 20″ inside diameter.

The furnace is entirely external, and has already been described.

There are 2 internal flues, 15″ in diameter and of $\frac{1}{4}''$ wrought-iron. At the after end the $\frac{1}{4}''$ end-plate is flanged outward, incasing the projecting end of the flue, to which it is then riveted. This arrangement is supposed to offer the least hindrance to the passage of the hot gases. The top of flues is 17″ below top of shell, and the two flues are 18″ between centers, leaving 3″ clear space between them.

There is 1 man-hole, $9\frac{1}{2}''$ by 15″, in the after end of each boiler; its lower edge is $\frac{1}{2}''$ below low-water line, $13\frac{1}{2}''$ from top of shell. To strengthen the boiler a wrought-iron elliptical ring $\frac{3}{8}''$ thick is riveted around the man-hole. The man-hole cover is of cast-iron, and of the ordinary shape.

There is a hand-hole, 4″ by 6″, in the lower part of forward end; its lower edge is 2″ from shell. It is not strengthened in any way.

There is no superheating area or apparatus connected with these boilers.

The feed apparatus is the usual "doctor," using the upright outside-plunger rotary-pump. It has two sets of pumps; the first draws the water from the river into the heater, and the second forces it into the boiler at a temperature of about 180° and a pressure of often 150 pounds per square inch. The pumps are 5″ diameter by 13″ stroke. The Snowden heater, a type of open heater in common use on western rivers, is here employed.

No surface blow-off is in use, but the ordinary bottom mud blow-off apparatus is attached to the mud-drum.

Two mud-drums are used as sediment collectors. One of them is placed at the second sheet from the after end of the boiler and the other just aft of the bridge wall. The feed-water passes through the after one, and the former one is used as the principal blow-off. They are 15′ long by $16\frac{1}{2}''$ inside diameter, with center lines 20″ below bottom of shell. They are set up at right angles to center line of boilers, and are joined to each boiler by 8″ cylindrical legs.

A copper steam-pipe, 6″ diameter, leads from steam-drum to throttle.

The safety-valve is of the ordinary weight and lever type, one on each boiler. Each valve has an area of 11 square inches. The lever is 4′ 3″ long, notched at intervals. The weight is $9\frac{1}{2}$ by $9\frac{1}{2}$ by 8, of cast-iron, and weighs 200 pounds. It is set to blow off at 140 pounds pressure per square inch, and its position must be 31″ from fulcrum, or 27″ from valve-stem.

Fusible plugs are put in top of flues and in shell just below water-line.

One pressure-gauge is placed at the throttle and one at front of boilers for guidance of firemen.

Two kinds of water-gauges are put on each boiler. The ordinary gauge-cocks, ten on the four boilers, and one low-water globe-gauge on each.

The ends of the boilers are strengthened by stay-rods joined to the shell, two at each end of each boiler. They are $1\frac{1}{4}''$ wrought iron and ends are riveted to shell and boiler-heads.

The only clothing the boiler has is a covering of red bricks laid in sand. The spandrils above top of combustion chamber are filled with mortar.

Each boiler is supported by a $\frac{1}{2}''$ wrought-iron ring, 3″ wide, riveted to the boiler and resting on the boiler front. This in turn rests on a 6″ by 10″ wooden beam, resting on main deck. At the after end of the boiler the support comes through the mud-drum, which is carried by cast-iron legs, 3″ by 5″, resting on a 5″ by 12″ wooden beam, similar to the one at the forward end.

Under the boilers the hull framing is much strengthened. Just under the forward and after supports "boiler beams" and braces, forming a truss, are placed, and between a pair of deck-beams is fixed a pine beam, 15″ by 10″, 15′ long, joining at each end to a curved oak beam, 9″ by 7″, resting in a shoe on the outer row of bottom stringers. This end is tied to the one on the opposite side of the boat by a wrought-iron bar, $2\frac{1}{2}''$ by $\frac{1}{2}''$. The weight of the boiler and contents is thus distributed more uniformly over the boat's bottom.

GENERAL DESCRIPTION.

Number of boilers	4
Number of furnaces	1
Grate area .... square feet	70.8
Total heating-surface .... do	1,431.2
Effective heating-surface .... do	1,022.6
Square feet total heating-surface per square foot grate area (about)	20
Best practice (Shock)	25 to 35
Square feet effective heating-surface per square foot of grate area	$14\frac{1}{2}$
Square feet calorimeter through flues	9.82
Square feet grate-surface per square foot of same	7.2
Best practice (Shock)	5 to 8
Square feet area stacks (2)	14.14
Square feet grate-surface per square foot of same	5
Best practice (Shock)	6 to 9

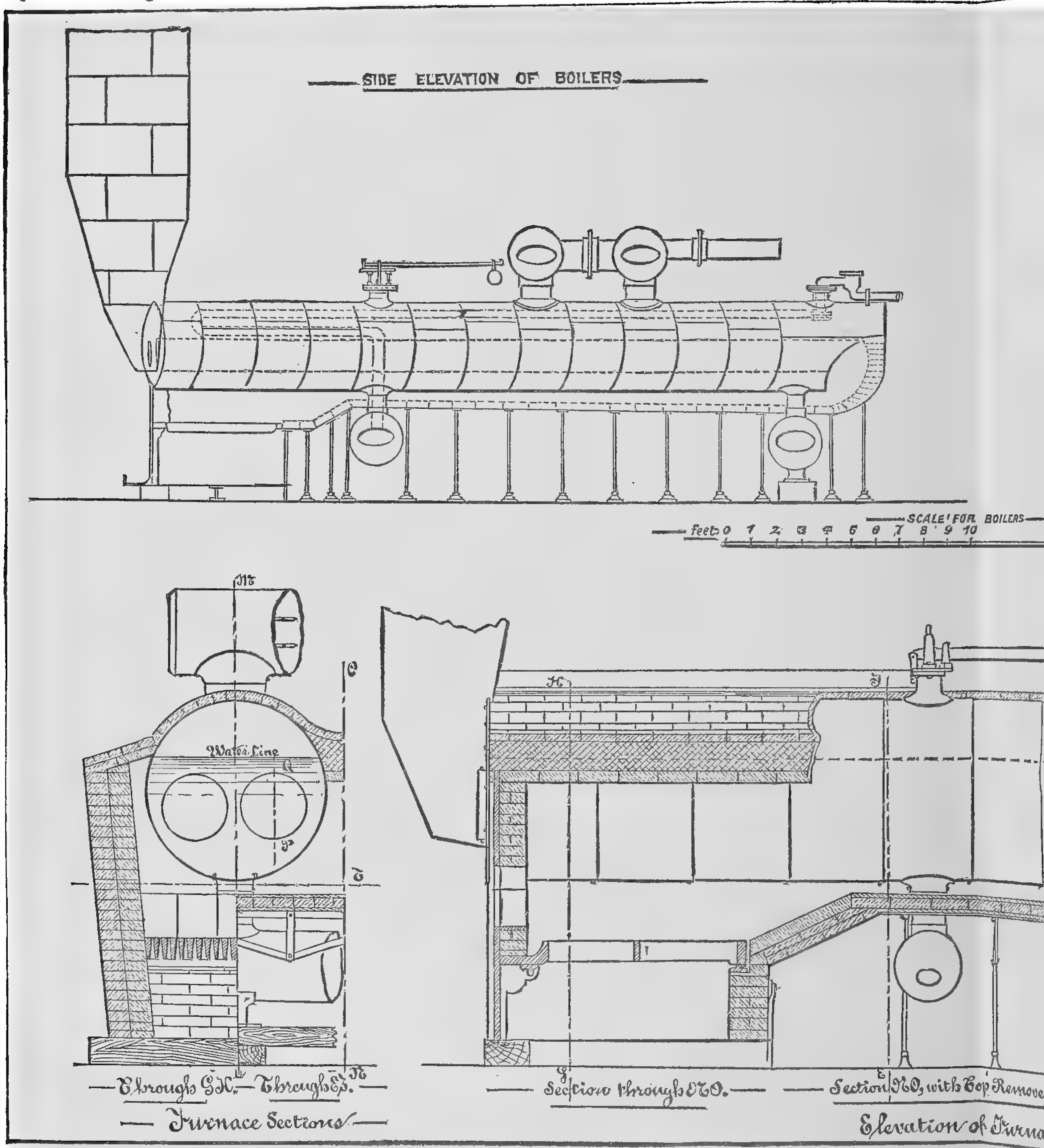
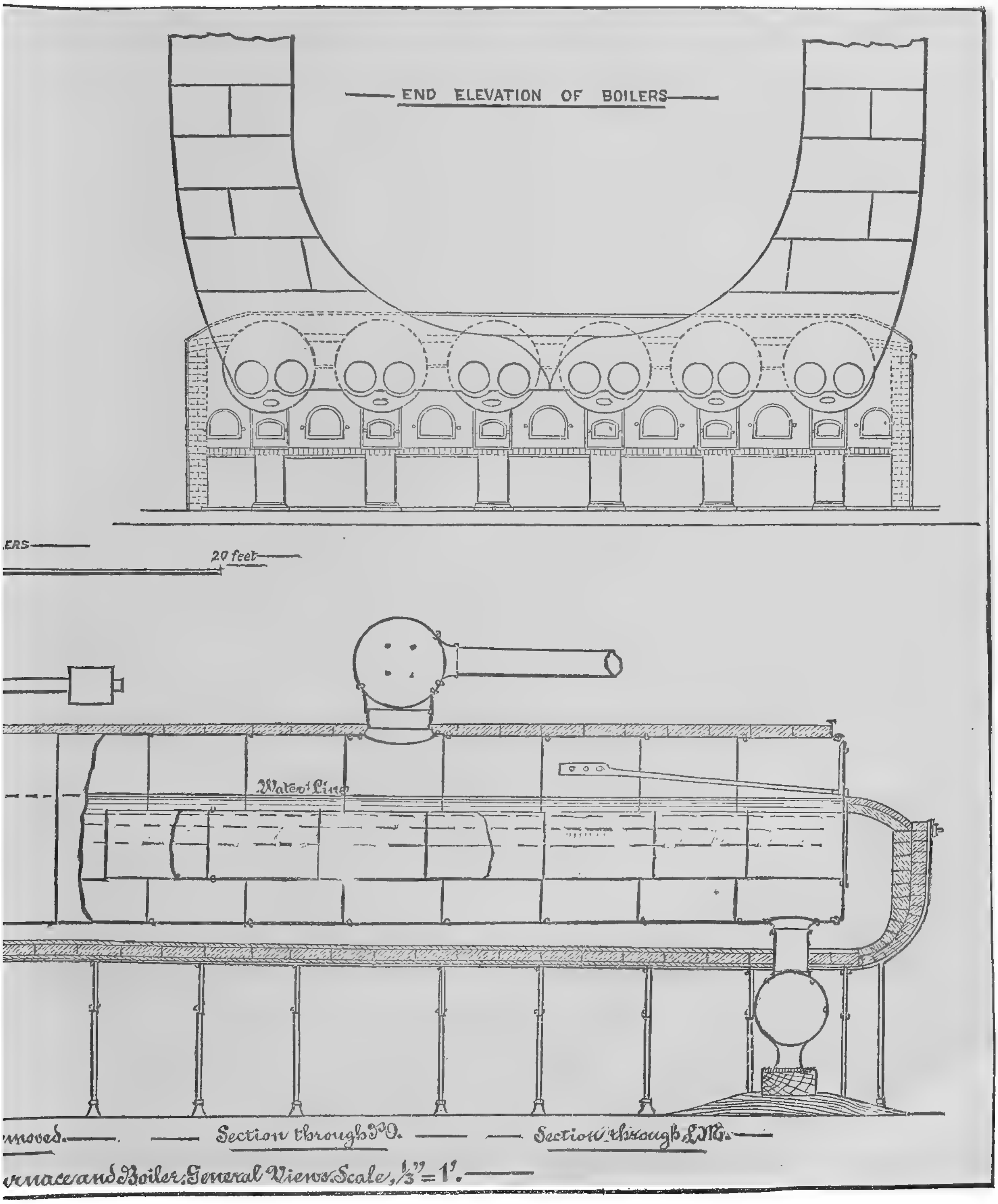

SIDE ELEVATION OF BOILERS
SCALE FOR BOILERS
Feet 0 1 2 3 4 5 6 7 8 9 10
Water Line
Through G.H. Through E.F.
Furnace Sections
Section through E.C.D.
Section K.D, with Top Remove
Elevation of Furna

FIG. 34.



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Square feet calorimeter over bridge	15.27
Square feet grate-surface per square foot of same	4.6
Best practice (Shock)	7 to 8

(But with forced draft this must be less, and present proportions are nearly correct.)

Height of stack above grate ... feet..	53.3
Total cubic feet steam room	562.26
Total cubic feet water room	294.4
Same in United States gallons	2,208
Total estimated weight of four boilers, with steam dome and mud-drums ... pounds..	29,263.7

(The weight of other attachments to boiler will bring this up to 15 tons.)

Weight of stacks ... pounds..	2,357
Weight of grate ... do....	5,700
Weight of water in boilers ... do....	18,350.9
Total weight of boilers, water, stack, grate, etc ... do....	55,671.6
Height of boilers from deck to top of shell	7′ 2″
Height of boilers from deck to top of dome	9′ 5″
Length taken up in vessel by boilers, etc	29′ 7″
Length, including fire-room and coal-bin	40′
Width of same	19′ 3″
Area displaced in vessel ... square feet..	77.2

In the above description, the term "furnace" is applied to a battery of several boilers.

The illustration, Fig. 34, exhibits two batteries or sets of river-boat boilers, the upper part showing two views of the boilers of the "Joseph B. Williams," and the lower part two views of the boilers of the "Montana." These represent the best class of boilers on the Mississippi valley steamers, and are very similar in general design and arrangement, both having furnaces between the cylindrical boiler-shells and a like arrangement of breeching and supports. The six boilers of the "Joseph B. Williams" are 40″ by 28′, of steel, shells $\frac{25}{100}$″ thick, 174 pounds pressure allowed, while those of the "Montana" are four in number, 42″ by 26′, of iron, shells $\frac{26}{100}$″ thick, 140 pounds pressure allowed. The "Joseph B. Williams" has two smoke-stacks, each 56″ in diameter and 56′ high.

The great relative size of boilers upon the Mississippi steamers is only with respect to the pressures. Actually the low-pressure boilers of the Atlantic are upon average larger for the same tonnage than the river-boat boilers, but in Class III, for example (steamers between 500 and 1,000 tons), multiplying the average boiler-volumes per 100 tons by the average boiler-pressures, we have the following products for the several districts specified:

Gulf district (Mississippi)	24,548
Lower Ohio district	24,230
Upper Ohio district	21,596
Saint Louis district	16,670
Upper Mississippi district	14,638
Pacific district (with Columbia river boats)	14,460
South Atlantic district	12,603
Western lake district	12,462
Eastern lake district	10,384
Middle states district	10,368
New England district	8,394

Where the "Dacotah" and the "Montana," of the Mississippi river, with about 25 cubic feet cylinder (of engine), each have about 1,000 cubic feet of boiler-volume, the "Harvest Queen," of Columbia river, Oregon, with tubular boiler and the same pressure (140 pounds), has about 670 cubic feet of boiler-volume to about 35 cubic feet of cylinder.

The arrangement of boilers on the river boats has been mentioned as requiring a great length of steam-pipe. The size of steam-pipe is a matter of engineering computation rather than a subject for statistics, but the saving in first cost of steam machinery by the use of high-pressures on the Mississippi steamers may be strikingly illustrated by a few comparisons. Where the main steam-pipe for the engine of the "Mary Powell" is 2′ in diameter, that of the "Montana," a boat of about the same tonnage, is only 6″; that of the "J. B. M. Kehloe," one of the largest steamers on the Mississippi, is only 7″ in diameter, and that of the powerful engines of the "J. M. White" is 12″, being uncommonly large for the Mississippi, while much smaller boats on the Atlantic have 15″ or 18″ steam-pipes.

PROPORTIONS AND ARRANGEMENT OF STEAMERS.

While there are some swift boats upon the western rivers they are principally side-wheel boats, stern-wheel boats not usually exceeding a speed of 10 miles an hour, although some state the maximum speed at 12 miles an hour. The stern-wheel boats, as peculiar to this section and as constituting about three-fourths of all the river steamers of considerable size, merit the chief attention, but the side-wheel passenger-steamers are also an important

type, their most characteristic feature being the employment of paired engines of long-stroke inclined from the horizontal. Of the proportionment of large side-wheel steamers upon the rivers of the Mississippi valley as compared with eastern practice, the following are fair examples:

Name.	Locality.	Tons.	Length.	Breadth.	Depth.	Ratio length to breadth.	Ratio breadth to depth.
			Feet.	*Feet.*	*Feet.*		
J. M. White	Mississippi river	2,027.76	312.6	47.8	10.2	6.55	4.68
Newport	Long Island sound	2,151.51	342.0	43.0	14.0	7.95	3.07
Guiding Star	Ohio river	1,121.97	304.0	41.6	7.1	7.31	5.86
Laura	Long Island sound	1,098.31	232.4	35.4	11.4	6.56	3.11
Bostona	Ohio river	993.52	302.0	43.4	6.0	7.17	7.23
Daniel Drew	Hudson river	930.35	260.0	30.0	10.0	8.66	3.00

The "Bostona" has side-wheels 27′ in diameter and 16′ face, and the "J. M. White" has side-wheels 44′ in diameter and 19′ face.

The "Wyoming," 1,034.15 tons, is one of the best examples of a stern-wheel boat. It is 257′ long, 45′.5 broad, 6′.3 deep; ratio of length to breadth, 5.65; ratio of breadth to depth, 7.22. The "Dacotah," 956.48 tons, is 252′ long, 48′.8 broad, 5′.5 deep; ratio of length to breadth, 5.16; ratio of breadth to depth, 8.86. A third example of a stern-wheel boat is one whose engines and boilers have already been illustrated, the "Montana." This has a registered tonnage of 959.47; length, 250′; breadth, 48′.8; depth, 6′; ratio length to breadth, 5.12; ratio breadth to depth, 8.13. The "Joseph B. Williams," 801.91 tons, is 220′ long, 40′ broad, 6′.5 deep; ratio length to breadth, 5.5; ratio breadth to depth, 6.15. The "Mollie Moore," 601.70 tons, is 238′ long, 40′.4 broad, 5′.2 deep; ratio length to breadth, 5.88; ratio breadth to depth, 7.77. Scarcely any boats that ascend the Mississippi are over 10′ deep, that being the depth of the "James Howard," 2,321.44 tons, while the "J. B. M. Kehloe," 2,293.78 tons, has a depth of only 8′.5, and the great majority of boats are less than 7′ deep. The draft of these boats, when heavily loaded, is a good part of their depth. The "Montana," 6′ deep, draws 5½′ of water (with a load of 1,300 tons).

Glancing over the data of the above boats, we notice that the ratio of breadth to depth is usually greater in the stern- than in the side-wheel boats. Thus for five stern-wheel boats it is 8.86, 8.13, 7.77, 7.22, and 6.15, while for three side-wheel boats it is 7.23, 5.86, and 4.68. The ratio of length to breadth is also less in the stern-wheel boats, being 5.88, 5.65, 5.5, 5.16, and 5.12 in five cases, while in three side-wheel boats it is 7.31, 7.17, and 6.55.

Stern-wheels are of smaller diameter than side-wheels but of great relative width. Upon stern-wheel boats the boilers are placed forward in a position similar to that usual upon side-wheel boats, but as the machinery is placed so much farther back in the former, it is sometimes balanced by placing the boilers farther forward. The stern-wheel construction saves a great weight of wheels and housings, and under the same load and with vessels of similar length the stern-wheel boat will draw only from half to two-thirds as much water as the side-wheel boat. It also affords more deck-room and is better adapted for freight service.

It is also said that in the elements of speed and adaptability for passenger traffic the latest stern-wheel boats approach very nearly the best side-wheelers. The "Montana" runs from Saint Louis to Pittsburg and return in about 18 days actual running time. This may be very good time for a freight-boat, but it could hardly be called high speed. Western river steamers are flat-bottomed boats, more or less carefully modeled, especially near the stem, and with a shear at the stern to facilitate backing and steering, as several rudders instead of one have often to be used upon boats with square sterns.

Of the stern-wheel steamer "Montana," the weight of hull (of oak and pine) is estimated to be about 310 tons, and an iron hull would probably weigh less than two-thirds as much. The bottom of the boat is slightly concaved near the stern, which is of advantage in reversing and increases the efficiency of the rudders in going forward. The keelson is entirely within the hull. The "Montana" has four rudders, two balanced rudders near the middle of the stern and two wing-rudders, one near each corner. The wing-rudders are 6′ or 8′ long and 6′ high. The displacement of the "Montana" is about 594 tons when drawing 18″ forward and 26″ aft, and about 1,855 (net) tons when drawing 5′ 2″ amidships under a load which causes the guards to touch water.

The arrangement of hog-chains and braces is in several systems of trusses both fore and aft, and across decks in some steamers. In Fig. 36 is shown a deck-plan of the "Montana," exhibiting the arrangement of boilers and engines and the positions of eight fore-and-aft trusses, beside the trusses which support the timbers bearing the stern-wheel. The "Montana" has no cross-deck systems, but has an additional system of fore-and-aft trusses on each side, which is commonly dispensed with. Side-wheel boats have these cross-deck trusses to support the guards and wheels, and many wide stern-wheel boats have them ranged about 20′ or 30′ apart. When a steamer is improperly loaded, or when, as is often the case, she gets aground, an immense strain may be brought upon these hog-chains. The flat bottoms of the boats are also designed with reference to their being stranded.

In Fig. 35 is exhibited a sheer plan of the towing-boat "Joseph B. Williams," showing the wheel, engines, principal boilers and smoke-stacks, and other details. The smoke-stack of auxiliary boilers for supplying steam for the engines of four steam-capstans is seen near the main engines. This boat is smaller than the "Montana,"

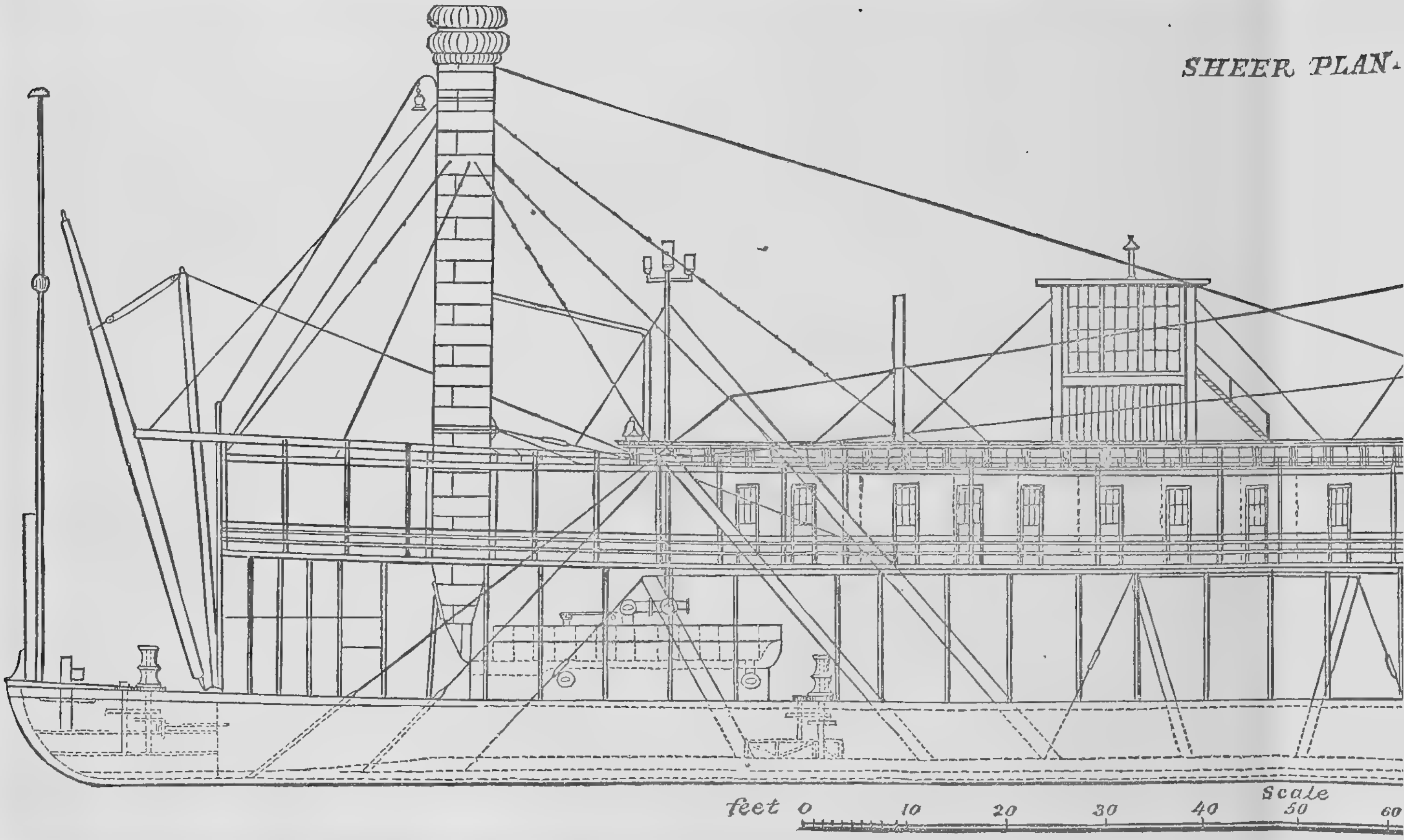
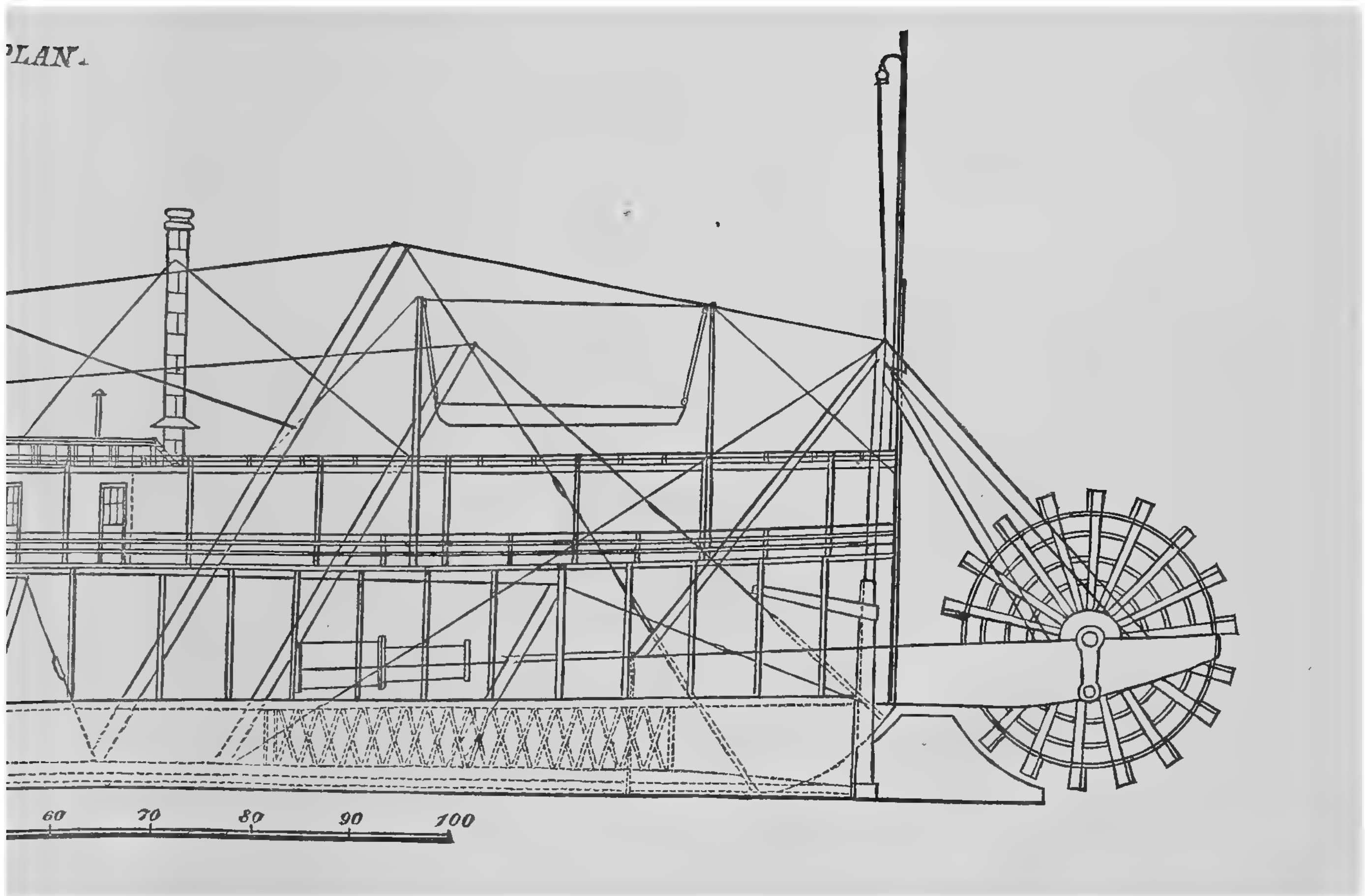


FIG. 35.


PLAN.
60
70
80
90
100

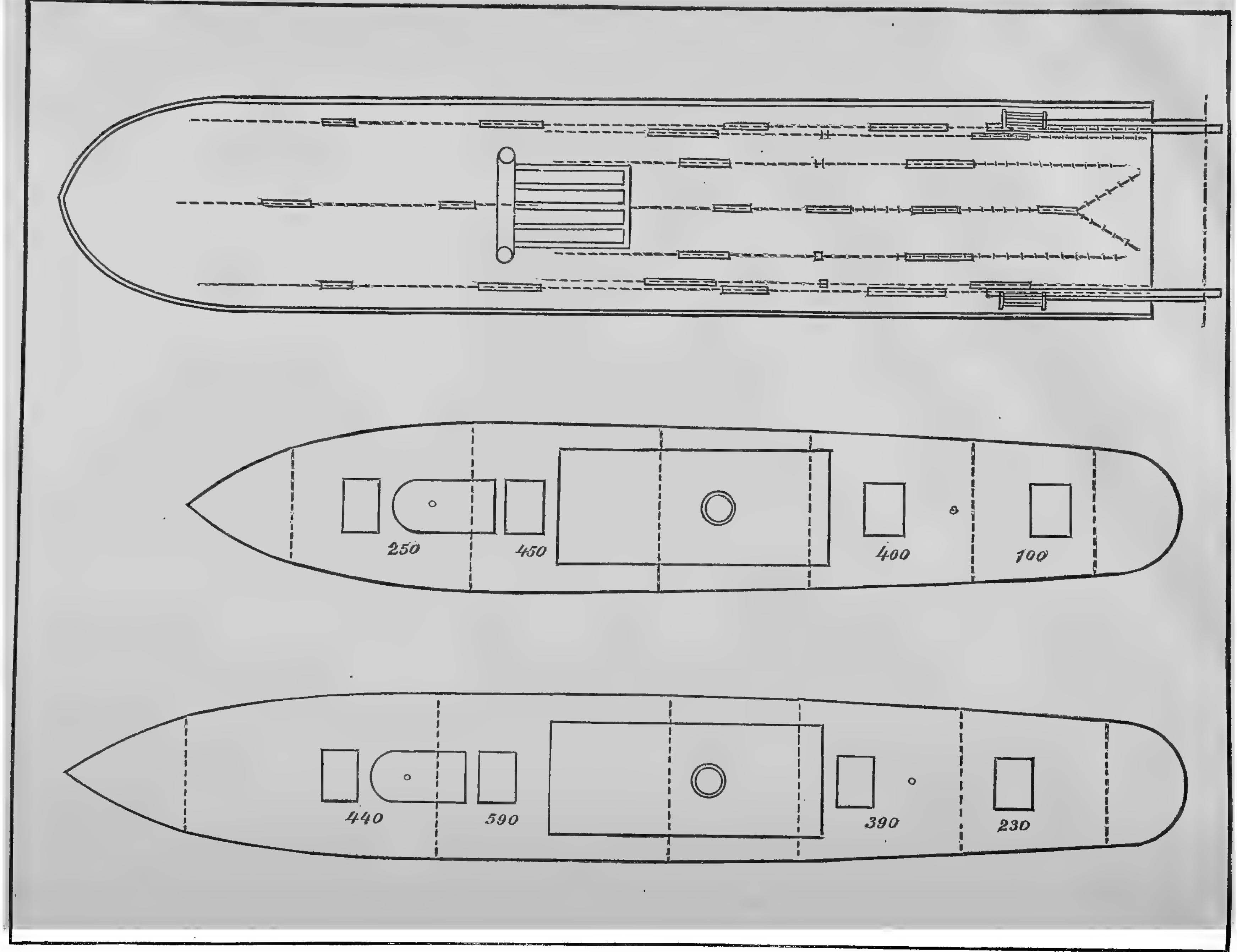


FIG. 36.

but it has very powerful engines. It carries 456 tons of coal on deck and consumes 27 tons a day as fuel. The towing capacity of the "Joseph B. Williams" is very remarkable, and illustrates the value of free inland waterways and the comparative cheapness of river transportation when contrasted with coasting traffic. In Fig. 36 are shown three plans of steamers, one of a stern-wheel river boat somewhat larger than the "Joseph B. Williams," while the others are of two Reading colliers—the "Perkiomen," which carries 1,200 tons, and the "Pottsville," which carries 1,650 tons of coal. The difference in plan itself presents a striking contrast between river and ocean practice. Upon the plans of the colliers, the large rectangle incloses the machinery and boiler space, with the smoke-stack. Smaller rectangles show the hatches, and very small circles the masts. The pilot-houses are also shown, and the numbers of tons accommodated by the several cargo spaces between the dotted cross-lines are marked in figures. In a year's time the "Perkiomen" made 41 voyages, carrying about 50,000 tons of coal and running in all nearly 39,000 miles. In a year the "Pottsville" made 41 voyages, carrying about 69,000 tons of coal and running in all nearly 38,000 miles. But the "Joseph B. Williams," in a *single* trip from Louisville to New Orleans, towed 32 coal-boats and barges, carrying 23,000 tons of coal, in one voyage transporting as much as the "Pottsville" would have done in one-third of a year or the "Perkiomen" (a boat of greater tonnage) in more than half a year. The "Pottsville" "cleared" 11 acres of 4′ coal-seam in one year, but the "Joseph B. Williams" "cleared" about 6 acres of 4′ coal-seam in a single voyage.

The average rate of freight received per ton of coal by the Reading colliers was as follows:

Year.	Rate.	Year.	Rate.
1872	$2 62	1876	$1 06
1873	2 32	1877	1 03½
1874	1 29	1878	91⅛
1875	1 15	1879	1 07½

The freight-bill for this trip of the "Joseph B. Williams" amounted to $11,500, or 50 cents per ton of coal.

Of a smaller stern-wheel boat, a good illustration is furnished by the "Tolima," a boat shown in plan and elevation in Fig. 44. This boat is 100′ long, 24′ broad, and 3½′ deep. It carries in all 50 tons on a 1′ draft, 100 tons on a 2′ draft, and 160 tons on a 3′ draft. It has a locomotive tubular boiler and a knock-down smoke-stack, being built for South American river service.

There are many small ferry-boats upon the smaller rivers. These are sometimes propellers, but often side-wheel steamers. The snag-boats are sometimes stern- and sometimes side-wheel boats. There are in the Mississippi valley comparatively few steam boats of small tonnage.

LAKE STEAMERS.

DISTRIBUTION OF THE SERVICE.

The following groups of steamers will specify the locality and character of the service comprehensively and with as much detail as the subject conveniently admits:

Steamers.	Steamers.	Tons.	Engines.	Cubic feet.
Steamers making long trips between the principal cities, Buffalo, Chicago, Milwaukee, Duluth, and Detroit.[a]	44	62,751.90	66	2,670.99
	22	18,718.85	24	588.78
Plying between Ogdensburg and Chicago	3	574.61	3	13.71
	1	86.60	1	0.54
Steamers plying upon the Illinois river. (See also Mississippi river steamers for boats plying below Peoria.)	1	536.08	2	44.00
	8	1,240.65	14	77.32
	13	1,178.31	19	12.70
	1	39.84	1	4.83
	5	64.73	6	2.25
Plying upon the Saint Lawrence river, not otherwise specified	2	299.85	4	19.46
	7	554.07	7	16.61
	8	279.81	8	5.87
	17	139.86	17	2.95
Plying in the vicinity of Chicago and Milwaukee, including canal service.	4	559.71	7	19.25
	8	623.77	10	20.01
	40	1,422.76	52	108.32
	28	461.98	30	29.58
Plying in the vicinity of Buffalo and Erie and upon the Niagara river.	3	688.08	4	33.93
	6	373.62	6	21.41
	14	462.96	16	25.37
	49	654.32	49	34.83

[a] The heaviest part of the traffic is between Buffalo and Chicago, but many of the large steamers also run to Duluth, and stop at Milwaukee or at Detroit. It is needless to remark that these are the largest and most important steamers upon the lakes.

Steamers.	Steamers.	Tons.	Engines.	Cubic feet.
Plying from Buffalo and Erie to New York (canal service)	26	3,413.53	26	83.59
Plying upon lake Saint Clair, the Detroit river and vicinity as far as Sandusky.	4	1,428.42	4	147.91
	7	493.02	7	9.83
	8	304.20	8	12.86
	16	183.00	16	8.06
Plying upon and from Green bay and tributaries	9	2,588.92	13	81.02
	14	1,043.46	27	50.36
	24	961.99	37	51.07
	22	348.21	28	14.59
Plying mainly along the east shore of lake Michigan	3	1,800.83	3	134.09
	21	6,952.72	26	165.71
	14	953.61	16	45.36
	28	1,026.05	32	52.62
	39	567.17	42	26.16
Plying mainly along the west shore of lake Michigan, north of Milwaukee and south of Green bay.	3	729.18	3	16.40
	1	75.00	1	2.95
	1	35.41	1	2.65
	3	25.86	3	2.24
Plying mainly in the vicinity of Grand Traverse bay and the straits of Mackinaw, and to the fishing grounds.	1	1,153.33	1	14.73
	1	335.64	1	12.28
	1	87.37	1	5.27
	16	587.10	21	28.44
	32	513.24	34	14.54
Plying mainly on and from Thunder and Saginaw bays	4	2,492.95	5	113.28
	17	4,774.70	19	442.19
	11	823.00	14	43.60
	11	376.14	11	17.41
	23	335.26	25	16.14
Plying upon lake Superior, not otherwise specified	2	624.14	2	44.47
	9	586.14	11	43.15
	14	474.68	16	29.90
	23	284.96	24	12.80
Plying upon lake Champlain	1	1,124.53	1	205.20
	1	643.14	1	105.56
	4	750.41	4	98.87
	7	455.86	7	42.19
	2	70.26	2	2.31
	11	102.79	13	3.56
Plying from Oswego and upon lake Ontario, not otherwise specified.	3	381.28	3	15.08
	3	234.44	3	6.11
	8	277.57	10	11.81
	17	228.83	18	11.56
Plying from Chicago and Milwaukee, not otherwise specified. Such steamers are engaged in a general lake service, which can not be more distinctly detailed.	4	4,746.71	5	198.13
	8	5,146.97	[illegible]	425.28
	8	3,069.80	8	146.28
	4	261.85	6	17.03
	6	215.95	7	14.73
	4	78.07	4	6.70
Plying from Detroit and Toledo, not otherwise specified	11	13,057.25	16	834.14
	12	8,420.77	12	885.34
	42	10,322.34	48	605.38
	5	403.86	6	29.04
	1	34.85	1	2.65
	17	202.17	17	13.93
Plying from Port Huron and Algonac, not otherwise specified	4	2,603.63	6	69.15
	21	5,658.78	21	155.88
	4	328.01	4	6.38
	1	36.79	1	2.95
	3	32.77	3	0.88
Plying from Cleveland and Sandusky, not otherwise specified	2	2,752.38	3	120.60
	8	6,988.80	10	143.89
	21	5,419.55	22	198.79
	9	698.77	10	28.43
	18	648.74	26	37.61
	20	270.04	26	19.10

Steamers.	Steamers.	Tons.	Engines.	Cubic feet.
Plying from Buffalo and Erie upon the lakes, not otherwise specified.	20	25, 944. 59	28	759. 68
	5	3, 349. 12	5	75. 69
	11	2, 545. 21	16	133. 30
	2	151. 16	2	9. 17
	2	88. 87	2	4. 08
	3	60. 07	3	4. 03

To the casual observer in glancing over these figures it may appear that the aggregate cubic feet cylinder capacity of engines in certain groups is sometimes disproportionately large compared with other groups of steamers of nearly the same aggregate tonnage. This is an indication of the larger employment of long-stroke paddle-wheel engines, while the smaller relative cylinder-capacities are peculiar to short-stroke engines driving screw-propellers.

ENGINES OF LAKE STEAMERS.

If compound and condensing engines be considered the standard of economy, the most advanced American practice in marine engines is found upon the large lake steamers. The following table presents by ports of inspection the numbers of engines used in propelling steamers of over 1,000 tons, the numbers of compound, simple-condensing, and simple non-condensing engines, and the numbers of engines used in driving screws and paddle-wheels:

Port of inspection.	No. of engines.	Type.			Used in driving—	
		Compound.	Simple-condensing.	Non-condensing.	Paddle-wheel.	Screws.
Buffalo	64	48	13	3	0	64
Cleveland	21	2	15	4	0	21
Detroit	20	6	12	2	3	17
Milwaukee	5	[illegible]	2	1	0	5
Chicago	4	1	3	0	0	4
Port Huron	2	2	0	0	0	2
Marquette	2	0	2	0	0	2
Burlington	1	0	1	0	1	0
Grand Haven	1	0	0	1	0	1
Total	120	61	48	11	4	116

In the relative showing of compound and condensing engines on large steamers, no other section of the United States will compare with this. These boats are almost invariably freight-boats, and as finely-built engines are put into them as into the finest passenger-boats. They make long runs and carry heavy cargoes, and economy of fuel is a more important consideration than upon the rivers of the Mississippi valley. The passenger-boats are more commonly of the side-wheel type with beam-engines, although some of the large propellers do a mixed freight and passenger traffic.

The compound engines are mostly of the steeple type, the high-pressure cylinder being placed above the low-pressure cylinder, but in other cases the cylinders are placed fore and aft, as is usual upon the Atlantic seaboard. In most of the steeple engines the high-pressure cylinder is made half the diameter of the larger cylinder.

Examples of steamers with fore and aft compound engines: The "Thos. W. Palmer," 1,096 tons, of Detroit, is 205′.8 long, 34′.5 broad, and 17′.7 deep. It has one 27″ and 44″ by 40″ engine, the smaller cylinder forward. The steamer "Amazon," 1,406.87 tons, had twin screws, driven by double compound engines 20″ and 40″ bores by 30″ stroke. These engines were built at the Cuyahoga works in Cleveland. The twin screws were 8′ 9″ in diameter, and 13′ in pitch.

The following are examples of steeple compound engines: The "Boston," 1,829.52 tons, is a steamer 263′.2 long, 36′ broad, 15′.4 deep. It has two steeple compound engines 20″ and 40″ bores by 42″ stroke. The steamer "Wocoken," 1,400.37 tons, of Cleveland, has a 30″ and 56″ bore by 48″ stroke steeple compound engine. The propeller-wheel is 11′ in diameter and 15½′ in pitch.

The "Waverly," 1,104.02 tons, is a steamer 191′.2 long, 33′.7 broad, 13′.45 deep. It has one steeple-engine 24″ and 54″ bores by 36″ stroke, driving a propeller-wheel 11′ in diameter and 15′ in pitch. The steamers "Delaware" and "Conestoga," plying between Buffalo and Chicago, have each one 24″ and 48″ by 48″ steeple compound engine, driving a screw 11′ in diameter and 15′ in pitch.

The new steamers "City of Rome" and "Cumberland" have compound engines with cylinders fore and aft, dimensions 32″ and 60″ by 48″, driving propellers 12′ in diameter by 14½′ pitch. For most of the foregoing steamers there are double feed-pumps, each having a 5″ plunger with 8″ stroke, and an air-pump 26″ in bore by

14″ stroke. Sixty-five to 75 revolutions per minute is the ordinary speed of engines, and the steamers are slow, making 8 or 9 miles an hour with a coal consumption of about a ton an hour. The usual draft of these steamers is 13′ or 14′ on the even keel.

The following description is given of the steeple-engines of the "Buffalo" and the "Chicago," of the Western Transportation line. These engines were built at the Globe Iron Works, Cleveland, in 1878–'79. The "Chicago," 1,847.37 tons, is 265′ long, 36′.8 broad, and 16′.4 deep. The "Buffalo," 1,762.85 tons, is 258′.8 long, 35′.9 broad, and 16′.2 deep. The engines are identical, two with four cylinders upon each steamer. They have rotary-valves and the general arrangement is illustrated in Figs. 37 and 38. Fig. 37 is a sketch in skeleton designed to show more clearly the connections of the moving parts and of the valve-gearing. In this figure fixed bearings are indicated by open circles and the framing is not drawn. At the right is indicated a hand-wheel with a screw operating a sector of a worm-wheel upon a rock-shaft, by which the link may be shifted. At the left the air- and feed-pumps are shown. The other figure shows the exterior appearance of the cylinders and connections. Since, for the sake of clearness, shading and details of the supporting frame are omitted, it ought to be said that for handsome and thorough workmanship these engines are to be highly commended. In the figures only one engine is shown in side view, there being two engines combined, two 20″ by 40″ cylinders and two 40″ by 40″ cylinders. The high-pressure cylinders cut off at 8″, expanding 32″. There are two air-pumps, each 22″ bore by 12″ stroke, and two double-acting feed-pumps, each 4″ in diameter by 12″ stroke.

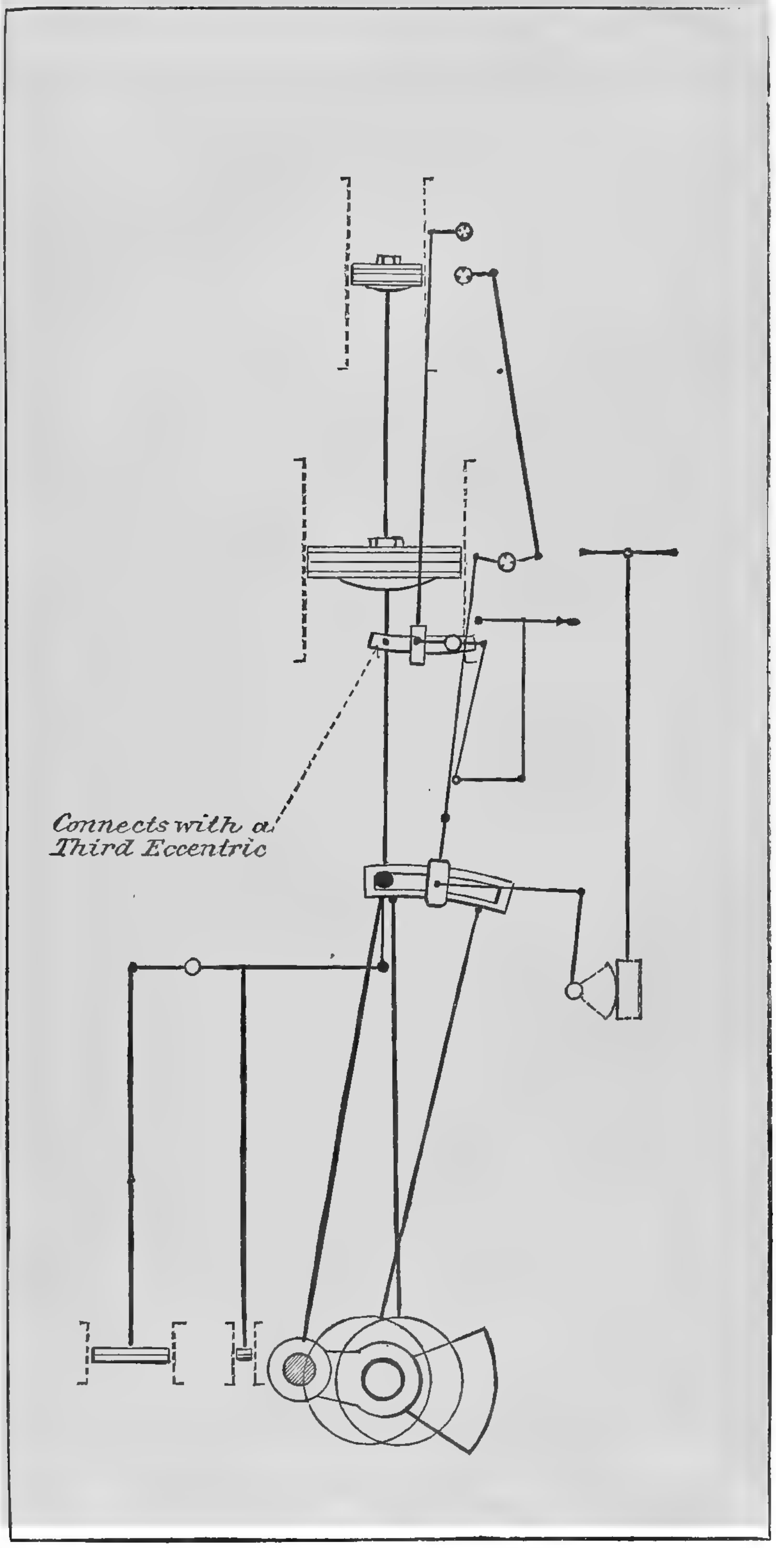


Fig. 37.

At an engine speed of 80 revolutions per minute the speed of steamers is 10 miles an hour. The coal consumption does not probably exceed $2\frac{3}{4}$ pounds per horse-power per hour. The draft of the steamers is 16′ on the even keel. The engines and boilers weigh about 100 net tons. All of the bearing surfaces have brass boxes instead of the cheaper expedient of Babbitt metal.

Of the simple condensing-engines for screw propulsion upon the lakes perhaps no better example could be adduced than the double engines of the "E. B. Hale" and "Glydon." The "E. B. Hale," 1,186.15 tons, of Cleveland, is a steamer 217′.3 long, 34′.8 wide, and 17′.9 deep. It has two 36″ by 36″ inverted engines. These were built by the Globe Iron Works and have slide-valves. They have two 22″ bore by 12″ stroke single-acting air-pumps, and two 4″ by 12″ double-acting feed-pumps. The engines make 80 revolutions per minute; the speed of vessel is 10 miles an hour, consuming about 1,400 pounds of coal per hour. The engines and boilers weigh about 80 net tons. The draft of the steamer is about 14′ on the even keel.

The steamer "Commodore," 2,082.02 tons, plying between Buffalo and Chicago, has two $22\frac{1}{2}$″ and 48″ (diameters) by 3′ stroke compound engines, driving a propeller-wheel 12′ 3″ in diameter, said to be the largest propeller upon lake Michigan.

The steamer "Transport," 1,594.93 tons, has four 28″ by 48″ condensing-engines.

The "Vermont," 1,124.53 tons, plying on lake Champlain, has one 56″ by 12′ beam-engine. The "City of Cleveland," 1,221.98 tons, of Detroit, has one 50″ by 11′ beam-engine; and the "Northwest," 1,109.19 tons, has one 60″ by 12′ beam-engine. Jet-condensers are used with all of these beam-engines.

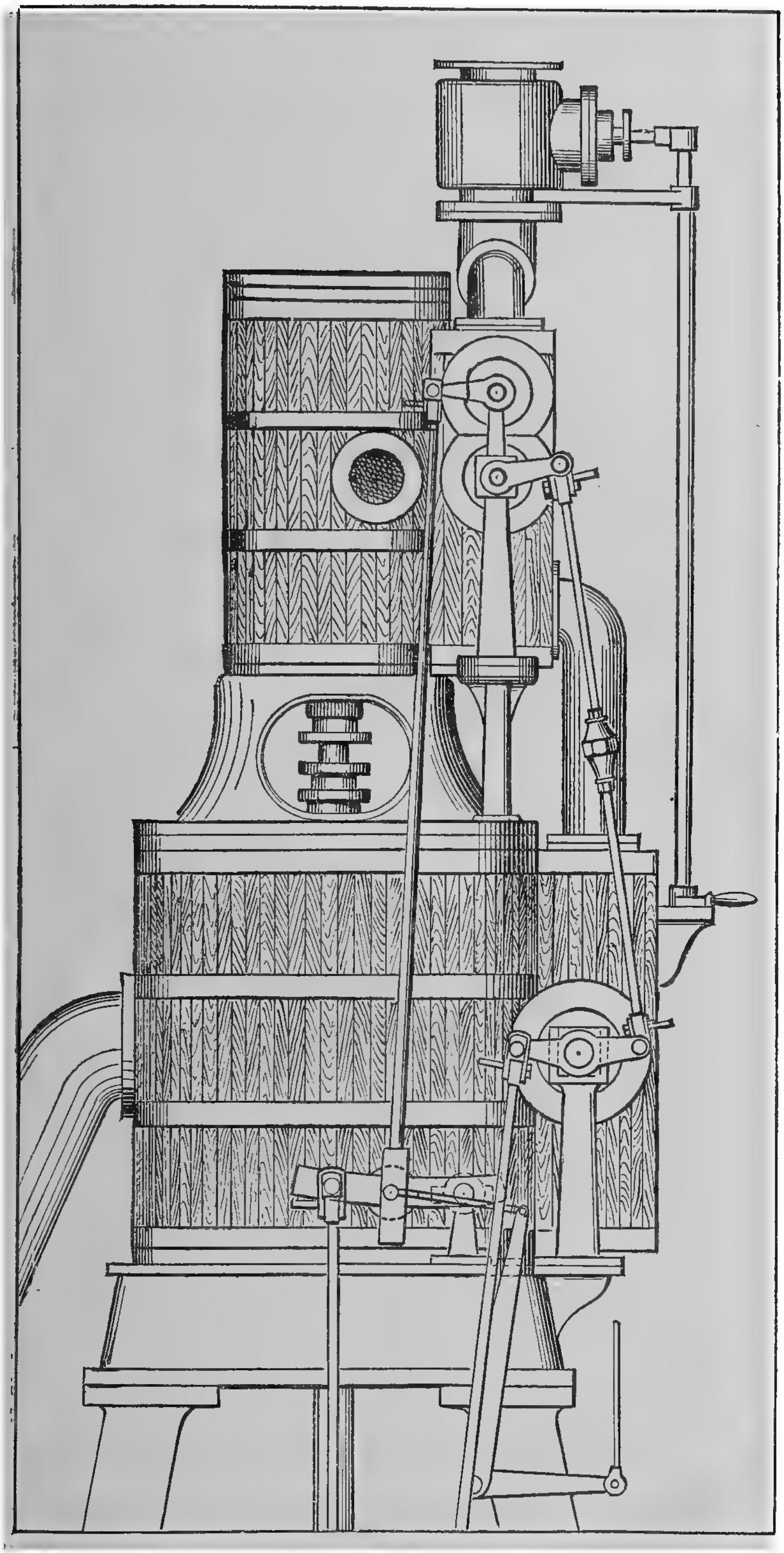


FIG. 38.

Upon steamers of Class II, of 77 engines 7 are compound (all these being upon steamers inspected at Buffalo) and of the remainder about half are non-condensing engines. Nearly four-fifths of them are short-stroke propeller engines, and the rest mainly beam-engines.

Upon steamers of Class III, of 248 engines 18 are compound, several of these being upon boats of the Erie canal. The non-condensing engines constitute about two-thirds of the remainder. Many of the condensers are used with beam-engines. The screw-propellers outnumber the paddle-wheel boats about 7 to 1. The "Relief," 267.33 tons, a towing-boat plying from Tonawanda to Lake Huron ports, has a non-condensing engine, one cylinder 25″ bore, 20″ stroke, with two pistons.

Upon steamers of Class IV all of the engines are simple non-condensing except 6 compound engines. The tug-boat "Brilliant," 66.69 tons, of lake Champlain, has one 17″ and 35″ by 22″ compound engine. The passenger-boat "Orizaba," 76.26 tons, plying from Buffalo to the Northwestern lakes, has one 15″ and 28″ by 16″ compound engine. The "Mystic," 74.90 tons, of Erie, has one 9″ and 16″ by 12″ compound engine. The canal-boat "B. and C.," of Chicago, 99 tons, has two $7\frac{1}{2}$″ and 14″ by 12″ compound engines. The canal-boats "M. Talcott" and "Advance" also have compound engines.

While most of the small boats are propellers, some have side-wheels, with little distinctive change in the type of engine. Thus the little boat "Julia 2d," 6 tons, of lake Champlain, has side-wheels driven by an 8″ by 12″ engine.

The propeller "Jennie A. Sutton," 25.38 tons, plying between Elk rapids and Traverse bay, has a 10″ by 10″ simple non-condensing engine, and a 4′ (diameter) propeller which, under 80 pounds steam in the boiler, makes 205 revolutions per minute. The "Valley Mills," of Cleveland, is a paddle-wheel steam scow. Its dimensions are, length 70′, breadth 13′, depth 5′. It has two 6″ by 32″ non-condensing engines, and a 4′ by 9′ tubular boiler. It plies over a 12-mile route on the Cuyahoga river. Among these small boats one will look a long way to find a condensing-engine, but a few boats have them. The "Bonnie Castle," 4.75 tons, plying on the Saint Lawrence river, has one $5\frac{1}{2}$″ by 8″ condensing-engine. The yacht "Truant," 32.14 tons, of Detroit, has a 9″ and 16″ by 12″ compound engine, and a patent vertical boiler 5′ by 9′ (high) of steel. The "Sylph," 8.86 tons, plying upon Detroit river, has a $14\frac{1}{4}$″ by 6″ trunk engine. The yacht "Maud Lilley," 13.79 tons, of Grand Haven, Michigan, has an 8″ diameter by 6″ stroke oscillating engine.

EARLY EMPLOYMENT OF COMPOUND ENGINES ON THE LAKES.

In 1850 the engines of the "Buckeye State" were built at the Allaire Works, New York, from designs by John Baird and Erastus W. Smith,* and the following year the steamer was put upon the lake route between Buffalo, Cleveland, and Detroit, and, having compound engines, consumed less than two-thirds as much fuel as a steamer of the same line having a single-cylinder engine. The "Buckeye State" had a beam-engine of 11′ stroke, compound, a high-pressure cylinder of 37″, and outside of it like an annulus a low-pressure cylinder of 80″ diameter, the low-pressure cylinder thus having about $3\frac{1}{2}$ times the area of the high-pressure cylinder. The pistons were connected with one cross-head (something like the Hartupee compound engines) and the remaining mechanism was similar to that of ordinary beam-engines. The engine is stated to have been the first compound vertical beam-engine built for marine service, and its early employment upon the lakes seems to have been a lesson not lost upon lake practice. Other compound beam-engines were built (for Hudson river service) having a second cylinder something as in the engines of the "Louisiana," but all have now gone out of use. The beam-engines of the lakes and the side-lever engines of the ocean were soon crowded aside by screw propulsion, with its short-stroke direct-acting engines, but upon the lakes the compound principle seems never to have been lost sight of.

BOILERS OF LAKE STEAMERS.

On steamers of Class I nearly all of the boilers are return-tubular, either of the fire-box or marine type, generally the former. The "C. J. Hershaw," 1,323.95 tons, of Milwaukee, with one 48″ by 3′ condensing-engine, has one $9\frac{1}{2}$′ by 18′ cylindrical flue and tubular boiler, called of the marine type. It has seven 13″ and two $9\frac{1}{2}$″ flues and one hundred and sixty 3″ tubes. The area of safety-valve is 28″; the pressure allowed, 50 pounds. The feed is heated to 100° Fahr., and one $4\frac{1}{2}$″ by 12″ feed-pump is employed. The "E. B. Hale" has one 12′ by 18′ tubular boiler, with two furnaces, 70′ of grate- and 3,300′ of heating-surface, about $1\frac{3}{4}$ times as many square feet of heating-surface as total cubic feet of volume. The "Buffalo" and "Chicago" have each two 8′ by 16′ compound cylindrical tubular boilers, with fire-boxes and two furnaces to each boiler. For the two boilers in each vessel the grate-surface is 100 square feet; effective heating-surface (below water-line), 3,346 square feet; ratio of heating-surface in square to total volume in cubic feet, about 1.8.

Forty-three out of one hundred and eighteen boilers are of steel, or have steel shells, some boilers having steel shells and iron furnaces. The steamer "Transport" has four 9′ 4″ by 16′ fire-box cylindrical return-tubular boilers of Otis steel. The thickness of shells ranges from $\frac{5}{16}$″ to $\frac{7}{8}$″, and the boiler-pressure allowed from 36 to 113 pounds per square inch.

Of boilers upon steamers of Class II, about 5 per cent. are of steel, or partly of steel, some having steel furnaces or fire-boxes and iron shells. The fire-box return-tubular is the usual type, and the ordinary range of pressures allowed is from 40 to 90 pounds. The steamer "Iron Age" has a wagon-top boiler.

Upon steamers of Class III fire-box and return-tubular boilers are the prevailing type. There are a few direct-tubular boilers, and out of a total of 244 about 30 vertical tubular boilers, 25 of which are upon boats inspected at Buffalo, and mainly in the canal and freight service. One boat, 336.10 tons, of Green Bay, is specified as having two 54″ by 12′ vertical boilers, without tubes or flues. The new passenger-steamer "Grace McMillan," of Detroit, has a registered tonnage of 312, one 32″ by 10′ beam-engine, and one 9′ by 16′ cylindrical arch-flue and return-tubular boiler of Otis steel. The shell is $\frac{5}{16}$″ thick, and 58 pounds pressure is allowed. The vertical tubular boilers upon the canal-boats are from 37″ to 57″ in diameter and 9′ to $10\frac{1}{2}$′ high. Some of them have automatic feeding attachments, and are known as the Wright automatic self-feeding canal type of boiler. Less than 10 per cent. of the boilers of this class are of steel, and nearly all of these are the vertical tubular boilers upon the canal-boats.

The return-tubular type holds its own even upon steamers of 25 tons and under. Among the smaller steamers there are of course a considerable number of vertical and locomotive tubular boilers and occasionally a wagon-top or other exceptional boiler appears in service or a return-flue boiler borrowed from river practice, but these cases are unimportant. I do not know of a rectangular boiler upon the lakes. Steel boilers are the rare exception. The canal-boat "Whale," 88.99 tons, of Chicago, has one 44″ by 12′ 6″ locomotive-boiler; thickness of shell, $\frac{35}{100}$″; material, steel; pressure allowed, 130 pounds. The canal-boat "B. and C." has a 54″ by 11′ vertical tubular boiler of iron; thickness of shell, $\frac{35}{100}$″; pressure allowed, 142 pounds. These pressures are much above the average.

A number of the small boats on Lake Champlain have vertical tubular boilers. The "Little Nellie," 15.57 tons, has a $4\frac{1}{2}$′ by $6\frac{1}{4}$′ vertical tubular boiler; thickness of material (iron), $\frac{3}{8}$″; pressure allowed, 70 pounds; safety-valve area, 4″.4. The feed is heated to 180°, and an injector and a 3″ by 4″ pump are used.

PROPORTIONS OF LAKE STEAMERS.

While the practice in the employment of engines upon the lakes may be considered to be highly advanced, until recently but very little attention has been given to the modeling of large vessels, and the large freight-

* Erastus W. Smith was the designer of the engines of the "Bristol" and "Providence," and other notable steamers.

boats have been described as boxes modeled only at the ends. Of a large freight steamer, the "Wocoken," recently launched, it was said that her model was unusually fine, more like an ocean steamer than a lake vessel, showing that the models of lake do not commonly compare with those of ocean steamers. The principal dimensions of some of the large freight propellers are as follows:

Name of vessel.	Length.	Breadth.	Depth.
	Feet.	*Feet.*	*Feet.*
Rochester	266.9	40.0	16.0
Commodore	265.4	42.2	15.4
Wocoken	251.6	37.3	18.5
Conestoga	252.8	36.0	16.2
E. B. Hale	217.3	34.8	17.9
Henry Chisholm	256.5	39.3	20.3
Buffalo	258.8	35.9	16.2
Philadelphia	236.0	34.3	14.0
Colorado	254.6	35.0	13.0

For the average of these, the ratio of length to breadth is 6.75 and the ratio of breadth to depth is 2.27. In point of depth they stand intermediate between the river and ocean steamers.

The following are examples of Chicago canal-boats:

	Length.	Breadth.	Depth.
	Feet.	*Feet.*	*Feet.*
Victor	99 0	17.4	7.0
Advance	113.1	16.9	6.4
B. J. Moore	124.6	18.0	5.6
Novelty	194.0	17.2	7.6

There are upon the lakes a greater relative number of small yachts and steamers of under 50 tons than in any other section. The western rivers have few such craft, but they constitute by number more than half the steamers on the lakes, and these small boats upon the lakes constitute over 10 per cent. of the whole number of steamers in the United States, and over one-fourth of all the small steamers in the United States. (Of the whole number of steamers in the United States, it may be remarked that $6\frac{1}{2}$ per cent. are over 1,000 tons, 15 per cent. over 500 tons, $43\frac{1}{2}$ per cent. over 100 tons, $60\frac{1}{2}$ per cent. over 50 tons.) The following are the dimensions of some of the steam-yachts upon the lakes:

	Tons.	Length.	Breadth.	Depth.
		Feet.	*Feet.*	*Feet.*
Ben Drake	47.37	71.2	17.0	7.7
Willis Cotton	37.68	63.9	14.4	7.6
Golden Eagle	48.30	63.2	18.0	6.6
Gem	41.83	67.0	14.6	5.4
W. C. Tillson	49.44	53.0	15.0	7.0
C. P. Morey	20.28	63.0	14.0	7.0
E. P. Ross	28.12	57.4	16.6	6.6
Truant	32.14	76.0	15.9	5.0
Lillie	31.65	62.0	15.0	4.8
Herald	39.44	80.2	11.5	5.5
Nonantium	37.04	59.4	13.5	4.5
Bret Harte	28.25	55.0	15.0	5.7

Excepting the "Herald," the above are comparatively bluff boats, ratio of length to breadth averaging about 4, of breadth to depth from 2 to over 3, showing them to be comparatively deep.

The side-wheel steamers of the lakes are of similar proportions to those used in sound and seaboard service. The "City of Cleveland," 1,222 tons, is said to be the fastest boats on the lakes. This boat was designed by Frank E. Kirby, and is unique in having feathering paddle-wheels. These wheels are 23′ in diameter, 9′ face, and 33″ wide, with 12 buckets on each wheel. The registered dimensions of the boat are: Length, 225′.2; breadth, 32′.4; depth, 13′.3. The keel is 226′ long, the length over all is 238′, and the breadth over all 54′. The draft is 7′. A beam-engine, condensing, 50″ diameter and 11′ stroke, and two fire-box and return-tubular boilers comprise the principal machinery. Each boiler-shell is about 11′ in diameter by 18′ long, and in each boiler there are 3 furnaces, and one hundred and twenty-two 4″ tubes 12′ long. The total grate-surface is 120 square feet; heating-surface, 4,400 square feet.

The feathering paddle-wheels as employed on the "City of Cleveland" are a departure from American in favor of English practice. English side-wheel steamers have usually small feathering-wheels, but with direct-acting engines. It is maintained by some engineers that these are preferable to the American type of large fixed paddle-wheels with beam-engines, but the latter certainly give great speed and endure great wear. On the other hand, side-wheel tugs are the most usual English type, while, except upon the rivers, the screw tug is almost universally employed here, being regarded as an improvement upon the side-wheel tug.

COST OF STEAMERS.

In large steamers the machinery, engines, boilers, and shafting, with propellers, usually weigh from 6 to 12 per cent. of the tonnage of the vessel, and for iron steamers cost between one-third and one-fifth of the whole cost. By the pound the machinery costs three or four times as much as the hull. For smaller boats the relative weight and cost of the machinery is greatly increased, and for small tug-boats the machinery may weigh one-fourth of all and cost fully as much as the hull.

Steamers are short-lived property. Their average life is inside of twenty years, and their value meanwhile rapidly depreciates, so that the selling value is no criterion of the cost. Other forms of property may increase in value, but as a rule the steamboat is worth more the year it is launched than it ever will be again. This point deserves to be emphasized, because false ideas of the relative cost of steamers in this country are often derived from comparisons between the cost of construction here and the advertised selling prices of old English steamers which have seen their best days, if they have not, with due respect to prudence, entirely outlived their usefulness. But if it be economy to buy old boats because they are cheap, old boats of American build are equally cheap. A large propeller was recently sold at a price equal to $15 per ton ($\frac{3}{4}$ cents per pound). This was built twenty-one years ago, and to-day would cost to build anew about $85 per ton, being a wooden boat. In attaining its majority it had thus aged away about 78 per cent. of its worth. A large Mississippi river steamer, with a wood hull, was built ten years ago at a cost, inclusive of machinery, of $80 per ton. After ten years' service it was valued about 37 per cent. off, or $50 per ton, and recently went out of service under conditions which cost the underwriters at the rate of $40 per ton.

Within the past few years the cost of English steamers of iron, large steamers of the best construction and with powerful engines, has been as low as $105 per ton, and steamers of an undesirable quality have been contracted for at as low as $50 per ton; but these rates were not maintained, and the tendency has since been upward, so that we may reckon the cost of large high-power passenger-steamers at $125 to $130 per ton, and smaller low-power cargo steamers at $80 to $90 per ton, these being iron boats. American ocean-going steamers are more costly, if of iron, but most iron steamers built in this country are vessels of a fine character, strong in build and of high power. The grain fleet running from New York is entirely of foreign vessels, but these are mainly an inferior and unsafe class of steamers, low-power freight-boats of foreign build, and not to be compared in quality with our swift coasting steamers.

In 1833 wooden ships were built in the United States at $50 per ton, and they can be built nearly as cheaply now, but steamers are more costly, as are iron vessels, although for the same carrying capacity the latter are lighter than those of wood. In California, where labor is not cheap, several large stern-wheel river boats have recently been built at a cost, inclusive of engines and boilers, of less than $65 per ton. These were good, serviceable boats, but not highly finished. The hulls were of wood.

Some of our large iron coasting steamers of recent build have cost over $200 per ton, but these were handsomely built and equipped and involved many experimental features. It is unquestionable that with an assured demand the best iron passenger-steamers could be built at less than $150, and good cargo steamers, with iron hulls, at less than $100 per ton. These figures are probably too high. Within the past year an iron side-wheel steamer, a swift, staunch, and finely finished boat, with a powerful beam-engine, has been turned out at a cost of $143 per ton. Some of the largest propellers upon the lakes, with iron hulls and compound engines of superior finish, have been built at a cost of less than $95 per ton. With a larger demand these figures could be reduced without loss to invested capital. It is of the highest consequence that the matter should be broadly considered, and that the types of marine machinery adopted should be of such wide adaptability as to secure an economical degree of uniformity in the system of manufacture. The preceding pages may be considered to contain an outline sketch of the entire marine plant of the United States. The building up of this plant makes a large demand, which, if properly met, permits in its very magnitude the exercise of the most profitable and economical methods of construction.

INDEX TO MARINE ENGINES AND STEAM VESSELS.

THE

ICE INDUSTRY OF THE UNITED STATES,

WITH A

BRIEF SKETCH OF ITS HISTORY

AND ESTIMATES OF PRODUCTION

IN THE DIFFERENT STATES,

BY

HENRY HALL,
SPECIAL AGENT.

TABLE OF CONTENTS.

LIST OF ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

NEW YORK, *June* 15, 1883.

Hon. C. W. SEATON,

Superintendent of Census, Washington, D. C.:

SIR: I have the honor to submit herewith a brief report on the ice industry of the United States. The starting point in this report is the amount of ice consumed by twenty principal cities of the country. The statistics of that subject were gathered by the special agents in charge of the census work in those communities. The figures cover the year from October 1, 1879, to September 30, 1880, which was the ice year corresponding the most nearly to the fiscal year for which general census statistics were collected. The winter of 1879–'80 happened to be one in which there was a partial failure of the ice crop in a few States; and the figures representing consumption in the summer of 1880 are, therefore, below the average of good years. However, they are a valuable indication of the ice industry in this country. To the data collected by the special agents of cities is added considerable matter of a general nature, obtained, incidentally, during a tour extending over nearly the whole country. The growth of the ice trade has been rapid during the last ten years. There has been a lack of exact statistics of the business, and ice dealers have long wished that an accurate and comprehensive report might be compiled to clear away exaggerations and remove all doubts as to the real magnitude and extent of the trade. An effort has been made to render this report the basis of a future more elaborate investigation, which will meet this want thoroughly. An acknowledgment is due to Robert Scott, esq., of New York, and Mr. Ballentine, of The Knickerbocker Ice Company of that city, and to the officers of The Louisiana Ice Company and The New Orleans Ice Company, of New Orleans, for valuable aid received.

Very respectfully,

HENRY HALL,

Special Agent.

THE ICE INDUSTRY OF THE UNITED STATES.

THE RISE OF THE BUSINESS.

Ice is one of the natural resources of the United States. Formerly regarded as worthless, of no possible utility whatever, it has come with the progress of the country in population and industry to be esteemed of the highest value and to form an important article of commerce. Its formation in the winter season is eagerly awaited by tens of thousands of men who make at least a part, if not all, of their living in collecting, storing, and distributing it for consumption, and by their employers, who, as is now estimated, have $18,000,000 of capital invested in the business, and whose profits are dependent upon the harvesting of a fair average crop of ice. The natural supply of ice in the United States is almost beyond calculation. In a good winter, not only are all the myriad lakes and ponds of the Northern States, except a few large and deep ones, frozen over to a depth of from 10 to 36 inches, but so are nearly all the running rivers. The water area thus covered with ice is so large that the supply aggregates several billions of tons. It would be difficult to compute the exact quantity which forms in any given winter, and no useful purpose would be subserved by any such calculation. It is enough that the supply is immensely beyond any possible requirements of the country. How small a body of water would supply the United States with all the ice it now consumes in one year would not be imagined, until after reflecting that a square mile of ice, 12 inches thick, weighs 700,000 tons. As not over 10,000,000 tons of ice are at present required by the country yearly, it will be seen that any little lake having 15 square miles of surface would yield an ample supply of this valuable commodity. It is not the quantity that forms in any given winter, however, which is of the greatest consequence. Interest attaches only to the quantity actually harvested and stored away in ice houses in the different parts of the country. The possession of such unlimited ice resources is of great importance to the United States. It is a remarkable fact that in some localities the communities already pay out as much money for ice in the course of the year as they do for fuel.

The people of tropical countries were the first to make use of ice, and it was natural that they should employ it to promote their personal comfort during the warmer months of the year. The article was, however, beyond the reach of the masses of the people. For many centuries ice was the luxury of the rich. It could only be obtained in small quantities, with much trouble, and at considerable expense. Only those who were in power, or those who were unusually prosperous in business, could afford to consume it. The first attempts at gathering and storing it were in Asia.

In India, the birthplace of so many of what have since become great and world-wide industries, ice was made by artificial means. Water was boiled to free it from the air it contained and was then exposed to the coolness of the night in porous earthen vessels, or in bottles wrapped with wet cloths. The evaporation of the moisture on the outside of the vessels produced intense cold within, and the water froze solid in the course of the night. Ice is still made in Bengal by this process. Shallow pits are dug, about 30 feet square and 2 feet deep, which are filled, to the depth of a foot or so, with sugar-cane, the stems of dried Indian corn, or straw. On this layer of rubbish are placed, at dusk, flat porous earthen pans, filled with water which has previously been well boiled. The dry northwest wind, which blows at night, converts the water into ice through the agency of evaporation; and the ice, being free from air bubbles, is as clear and hard as could be desired. At sunrise a large force of laborers go quickly to work, removing the thin sheets of ice thus formed to a deep pit, into which they are rammed down and left to congeal into a solid mass. The same practice, in principle, is in vogue in China. In the earlier ages of the Romans snow was annually collected on the dry plain of Hannibal's camp, on Mont Albanus, and rammed into cone-shaped pits, about 50 feet deep and 25 feet in diameter at the top. The pit was lined and covered over on top with straw and prunings from trees to preserve the store as long as possible in the summer

season. A thatched roof was placed over the pit and the doorway was well covered with straw when not being used. In summer the solidified snow was cut out with axes and picks and sent down to Rome for use. Snow is preserved in pits and caverns on Ætna and Vesuvius in substantially the manner just described, even at the present day.

In France, toward the close of the sixteenth century, during the reign of Henry IV, snow came into use for cooling liquors at the tables of the rich. Its sale became near the end of the following century a profitable trade. although never at any time a large one. The lack of rapid transportation on land restricted the trade. It is surprising, in view of the great abundance of shipping in the north of Europe at that time, and the great need of some means of keeping fresh the vast quantities of fish caught at sea by the Dutch, English, and Portuguese, that ice was not brought from Norway and Sweden by vessel to the southern countries. It seems to have been reserved to a later age, however, to ship ice by sea from northern latitudes, to reduce its cost to a point within the reach of all, and to make it an article of common and extended consumption. The experiment was not attempted until the nineteenth century; and indeed the whole matter of gathering and storing up ice in the winter time in northern regions, and the shipment of it by sea and land to points requiring it for consumption, as a regular business, have been the outgrowth of the last eighty years.

The development of the trade is one of the results of the progress of civilization. With increased density of population have come the growth of large cities, the discomfort of living in them in the summer season, a greater luxury of popular taste, and both the inventive ability and the wealth to gratify the new desires which have sprung out of this state of affairs. The demand for cooling drinks and frozen creams, even in the temperate zone, has become immense, and has been a powerful stimulus to the ice industry. Besides that, trades have sprung up, especially in the United States, which can be prosecuted only with the aid of ice, such as the transportation of fresh fish, meats, fruits, vegetables, and milk, and the manufacture and storage of beer, ale, wine, and butter; and these and other industries have led to even a greater consumption of ice than that which is called for by the gratification of luxurious tastes.

The ice trade of North America was created and begun by Frederic Tudor, of Boston, in 1805. The yellow fever was raging in the West Indies. The need of ice was so great that the idea of sending a ship-load thither as a speculation occurred to Mr. Tudor. A quantity was cut from a pond in the part of Lynn now known as Saugus, belonging to Mr. Tudor's father, and was sent down by wagons to Gray's wharf, in Charlestown, where it was stowed in the brig "Favorite," purchased expressly for the purpose. The shipment of ice has continued to center around Gray's wharf down to the present day, extending, however, in both directions to other wharves. The first cargo amounted to 130 tons, and the "Favorite" sailed with it to Martinique in 1805. Its arrival was heartily welcomed by the natives; but the shipper lost $4,500 on his venture. In 1807, a second shipment of 240 tons was made by Mr. Tudor, by the brig "Trident," this time to Havana. The enterprise was a novel one, and was regarded with much curiosity by American merchants, the majority of whom were in much doubt as to its probable success. Other occasional shipments were made, but all these early ventures were attended with loss and discouragement. Cargoes wasted greatly before they could be unloaded, and nearly 50 per cent. again before they could be distributed to consumers. The relations of the United States with European powers were complicated. Ships were interfered with and delayed. At one time an embargo was laid, and for two years the country was at war with England. After the close of hostilities, Mr. Tudor secured privileges that crowned his efforts with success. The British government released from certain heavy port charges all ships bringing ice to the islands under their control, and gave the enterprising merchant a monopoly of the trade. Jamaica was at that time the most valuable of the British West Indies; and at the port of Kingston Mr. Tudor established regular ice-houses for the storage of his cargoes, which gave him a solid and permanent footing in the business. In 1815, the Spanish government gave him certain privileges and a monopoly of the Havana trade. The business then became prosperous and profitable.

In 1817, Mr. Tudor sent a cargo of ice to Charleston, South Carolina. Like all the early shipments, it was a small one, not exceeding about 250 tons. Things have changed greatly since that time—single cargoes having been dispatched from northern ports to points southwards exceeding 1,200 tons. In 1818, Mr. Tudor extended his business to Savannah, Georgia. In 1820, he pushed on to New Orleans, and to accommodate his trade he built ice-houses there, to which the cargoes could be transferred immediately upon arrival. New Orleans soon became one of the most important points to him on the coast. The city grew to be the largest consumer of ice in the United States south of Philadelphia within thirty years of the shipment of the first cargo thither.

In the spring of 1833, Mr. Tudor tried the experiment of sending 200 tons of ice by sailing vessel to Calcutta, in India. The waste, during the long voyage of a hundred and eighty days, was about one-half the cargo, and although this loss was charged to the ice actually landed, it was found that ice could be delivered in Calcutta at one-half the cost of that made by the natives. As in the case of the earlier voyages to the West Indies, money was lost on the first venture to the East Indies; but the practicability of the trade was established, and Mr. Tudor persevered in it until it became a profitable source of revenue to him.

In 1834, the originator of this extended trade sent a first cargo to Rio de Janeiro, in Brazil. Until about 1836, the whole business of shipping ice by sea to distant ports was carried on almost exclusively by Mr. Tudor, and his

success earned for him the well-deserved title of the Ice King of the world. About 1837, his success attracted others to engage in the business. They were all at the port of Boston; and that city, being the birth-place of the trade, continued to be the base from which operations were almost exclusively carried on for more than fifty years from the beginning of its history. The port enjoyed the advantage of being able to obtain an abundant supply of the best quality of ice, from ponds in the immediate vicinity, and, by reason of the magnitude of its shipping interests, low freights to every part of the world; the business steadily increased, and was extended to China, Japan, and Australia.

In 1842, Gage, Hittinger & Co., of Boston, sent a cargo of ice in the bark "Sharon" to London, England, a city then dependent upon shallow ponds and a reservoir for an uncertain and limited supply of not very good ice. It is said that the fancy iced drinks, so common in the United States, were then almost unknown in England. In order to promote the consumption of the article he had to sell, Mr. Hittinger exported several competent bar-tenders from the United States to England, and introduced fancy drinks there. A Salem man afterwards chartered a ship to take 1,000 tons of ice to England at $10 a ton. Many ventures were made in this direction, and for a number of years American ice controlled the London market; but this branch of trade did not always produce satisfactory results. Norway ice could be landed in England at smaller expense, and although American efforts to compete with it were continued, they have finally ceased within two or three years. In 1880, Norway even exported a few cargoes of ice to America, on account of a brief prevalence of very high prices here. Many large fortunes were made in Boston by the early adventures in the ice trade. Frederic Tudor bequeathed over $1,000,000 to his heirs at his death, as the result of his energetic prosecution of the business he originated. He also left a large and established business to the Tudor company which succeeded him. The following table, prepared in 1857 by Mr. Tudor, will show the progress of the export trade of Boston down to about the outbreak of the late war:

Years.	Number of cargoes.	Quantity.
		Tons.
1806	1	130
1816	6	1,200
1826	15	4,000
1836	45	12,000
1846	175	65,000
1856	363	146,000

Mr. Tudor used to claim that the ice trade to Calcutta and the East Indies was one of the important forces that preserved the general commerce with that part of the world almost exclusively to Boston. He was of the opinion that it would have done the same in the commerce with China if the latter country had been in a more quiet condition. In a short report to the Boston board of trade in 1857, signed by Mr. Tudor and Timothy T. Sawyer, it was stated further:

> The freights paid to India amount to from 10 to 15 per cent. of the earnings [they were from $5 to $10 per ton] for the whole run of the ship out and home; and it is earned without cost or deduction to the charterer or ship-owner. So with vessels bound into the Gulf of Mexico. They take 50,000 to 60,000 tons annually, from which portion of the business the owners derive on the average $120,000 freight money, the shippers paying the expense of loading and discharging the cargoes. * * * This trade, founded on an article of no value, produces now a gross sale, at home and abroad, approaching $1,000,000, and calls into use other articles before worthless. For shavings, sawdust, and rice chaff, probably $25,000 are annually expended by the several companies now engaged in shipping ice. The planing mill which used to be troubled or burnt down by its shavings now has competitors to pay for them; and the saw-mill in Maine, to some extent, finds a customer for what is in its way. These small things, which formerly were a subject of cost to get rid of, now produce income. The average rate of freights for ice shipped at Boston is $2.50 the ton clean and clear to the ship-owner; therefore he received from this trade last year $365,000 (a large interest), and probably *more profit* than any other interest whatever in the business. Railroads and wagons were paid $100,000; laborers, $160,000; towns for taxes for ice privileges and ice in store, $1,500; and wharves, $20,000 to $25,000. There are 93 wagons and about 150 horses employed in distributing ice in Boston and vicinity; 60,000 tons are thus retailed, supplying 1,800 families, hotels, stores, and factories. The benefit of ice to steamers and passenger ships may be considered, as it has caused the nuisance of live stock at sea to be discontinued; ice preserves the fresh provisions. There are several manufactures which derive aid from ice. We hear no more of winter-strained oil, it being now better strained in summer than in winter. Salt and ice make the freezing mixture in August. The fisherman is beginning to half load his boat with ice going to Massachusetts bay, and returns with the fish as fresh as when first caught. * * * The ice trade was born here in Boston, and has been growing and extending itself with no successful competitor for more than half a century, and there is reason to think it is yet in its infancy.

It may be stated here that the exportation of ice grew to such magnitude as to warrant the construction of three fine wooden barks by the Tudor company a few years ago for their own trade. These vessels were the "Ice King," the "Iceberg," and the "Iceland," each of 1,200 tons register. They did good service for several seasons; but in 1880 the company was compelled to abandon its East India business on account of the manufacture of ice in the ports to which they had been trading for nearly half a century, and the vessels were sold.

As indicated in the foregoing report, the exportation of ice from Boston was accompanied by the growing up of a local trade as well. In order to preserve a part of the crop for summer use at home, Mr. Tudor stored it, as

indeed did all the early ice men in this country, in subterranean vaults or cellars, excavated usually from hillsides in the vicinity of the ponds. In this he followed in principle the ancient custom of the Romans. Sometimes all that was visible of the ice-cellar was the roof that covered the top of it. The door was through the roof, sometimes at the edge of the cellar. Later this form of storehouse was departed from so far as to leave three sides of the vault buried in the slope of the hill, the front of the house alone being visible.

Most of the modern improvements in facilities for cutting and storing ice are due to the inventive genius of Nathaniel Wyeth, the foreman of Mr. Tudor, and to John Barker, also in his employ; and it was owing to the first named of these progressive men that the old-fashioned vault was finally abandoned in favor of regular ice-houses, built first of brick and then of wood, and planted at the water's edge. Mr. Barker and Mr. Wyeth also invented a number of handy tools for use on the pond. The original outfit for ice-cutting consisted of little more than a number of axes, a few long cross-cut saws, each with one handle, and a few ice-hooks. Porous ice or snow was cleaned off either with axes or a rude hand-machine called a scrape. The taking out a supply of ice was a laborious process, usually consuming the whole winter. In place of the clumsy implements of the infancy of the business, horse-scrapers, ice-plows, chisels, breaking-off bars, hooks, etc., of various descriptions were invented, about 60 in all, which greatly simplified and lightened the work on the pond. These tools, modified year by year in the light of experience, and finally supplemented by introducing steam-power and an endless apron to elevate the cakes from the pond into the ice-houses, have completely revolutionized the whole business. By their aid 100,000 tons can now be cut and stored in the time formerly occupied in taking out 10,000 tons, not only increasing the certainty of harvesting a sufficient crop, but reducing the cost of the commodity to the consumer.

There is on record one earlier shipment of ice than that made by Mr. Tudor from Boston. It is said that in 1799 a gentleman in Charleston, South Carolina, chartered a vessel to go to New York for a cargo, and that the ice was cut on his order on a pond near Canal street and Broadway. No trade resulted from this pioneer enterprise, however. The early ice-cutting of New York was done for the benefit of a few marketmen who needed the means of preserving their meats for the wants of the population. A pond in the suburbs answered all purposes for many years. Afterward some ice was cut on Rockland Lake, the purity of whose water made its ice especially preferred. All the appliances of the early days were rude. The ice was taken out in cakes of irregular sizes, and was hauled away to the river on carts having wheels cut from logs of wood. It was sent to New York by sloop and tumbled ashore, there to remain until the cargo was landed, when it was hauled away to the storehouses. This primitive way of doing business answered until after the city began the career of expansion and activity following the opening of the Erie canal. More systematic methods were necessary, and various companies were formed with large capital, which operated at Rockland, Greenwood, Croton, and other lakes, and on the Hudson river above Poughkeepsie. Chief among the companies was the Knickerbocker, whose founder made a fortune like that of Mr. Tudor in Boston. This large and strong concern ruled the New York market for a period of twenty-five years. Its managers adopted all the newest inventions in the business and operated on a very large scale. They extended their trade to Brooklyn in time, and they are now the principal medium of supplying the two cities with ice. Of late years, a large number of new companies have come into the business.

In Philadelphia, the ice trade had an origin somewhat similar to that in Boston, except that the sick whose comfort was had in view were not residents of a foreign land, but were patients of the Pennsylvania Hospital. The managers of that institution laid in a yearly supply of ice along in the first part of the century, and often having more than enough for their own purposes, they advertised the surplus for sale. In 1811, Daniel George engaged in the business as a regular trade. Others followed him, and about 1820 something over 1,000 tons was being cut yearly for the local uses of the city. Two houses, each storing about 500 tons, are known to have been in existence in 1821, one owned by William Lee, the other by Henry Molier, both deep cellars covered over, and one at least of them built of brick. Some of the ice was delivered to consumers; but in the main the trade was carried on by offering it for sale from the ice-house. Small lots of ice were exported about this time, and fishermen began to buy it to keep their fish fresh until they could bring their catch to market. Twenty years later, the trade had grown to 7,000 or 8,000 tons yearly. In 1839–'40, an impulse was given to the business by Charles Carpenter, the founder of the Carpenter Ice Company, whose energy led to the harvesting of, annually, larger crops. In 1841–'42, the local supply failed, and Mr. Carpenter imported what he required from the northern coast. He passed by Boston and bought what he wanted in Halifax and other British American ports, bringing back huge cakes of thick, clear ice, weighing from 400 to 500 pounds apiece. The same year the Knickerbocker Ice Company, now one of the great concerns of the country, was founded by two old ice-men from New York, D. B. Kershaw and Horace Dennett, who brought to Philadelphia the labor-saving tools and the systematic delivery of ice in wagons. They erected in that year a 5,000-ton storehouse, and Mr. Carpenter built one of 1,000 tons. From that day to this the ice business of the city has been steadily expanding, until it has reached a total cut of about 1,000,000 tons yearly.

Following the lead of the eastern cities, all the communities of any size inland took up the gathering and distribution of ice as soon as their population was large enough to promise the consumption of 1,000 or 2,000 tons yearly. All the cities and many of the villages of the north adjacent to waters that freeze in the winter time now

have ice-houses of sufficient capacity to carry along all the ice that will be needed the following summer. The large cities have all grown into great markets for ice; and numerous small communities in the regions tributary to them, favorably situated for harvesting good crops, have developed a large industry in cutting and storing and selling the ice to the dealers of the larger cities.

The introduction of the use of ice into certain industries has been an important factor in building up this business. Take, for instance, the breweries. The brewers comprise the largest single class of consumers of ice in the United States. They have found that the use of ice for cooling the wort and regulating the temperature of the fermenting and storage rooms enables them to run their establishments the year around. It was the practice formerly to suspend operations in the summer time and make beer only in the cold weather. By running summer and winter both, the capacity of the brewery is nearly doubled. In fact it is in large part due to the use of ice that the manufacture of beer has developed so rapidly in the United States during the last twenty years. A large brewery will consume from 15,000 to 40,000 tons of ice a year, a small brewery from 1,000 to 10,000 tons.

Similar facts exist as to the meat-packing establishments, which have grown up so numerously in the west during recent years. They need ice to run to their full capacity, and by running the year around they give an immense amount of business to the ice companies. The growth of the business of transporting fresh meats, fish, fruits, vegetables, and milk has also added to the consumption of ice. In fact, ice having nearly doubled the product of these outside industries and trades, they have, in turn, fully doubled the product of the ice industry. The exact consumption of ice in the whole country cannot be reported, but it is the decided impression of leading ice men that if the exact facts could be known it would be found that the brewers, packers, and carriers of fresh provisions now consume more ice than do families, hotels, saloons, and ice-cream establishments.

A large ice business has grown up in the south since Mr. Tudor sent his first experimental cargoes to Charleston and Savannah. The supplies all came from the north at first, but during the last fifteen years a large business has grown up in the manufacture of artificial ice. Natural ice continues to be sent to the seaports of the south by northern operators, but inland at the south the trade is local and now almost wholly in artificial ice.

The following are the statistics of the trade in twenty principal cities in 1879-'80:

Name of city.	Tons harvested.	Tons sold and consumed.	Value of amount sold for consumption.
Boston, Massachusetts	660,000	381,600	$1,025,000
Providence, Rhode Island	41,000	33,000	320,000
New York, New York	1,885,000	956,500	6,190,000
Brooklyn, New York	528,000	334,500	1,900,000
Albany, New York	121,500	90,500	490,000
Troy, New York	52,000	43,500	235,000
Buffalo, New York	100,000	96,000	325,000
Jersey City, New Jersey	51,600	33,550	270,000
Newark, New Jersey	89,400	52,000	360,000
Cleveland, Ohio	146,500	129,800	320,000
Cincinnati, Ohio	283,000	206,900	1,200,000
Chicago, Illinois	710,000	576,700	2,400,000
Detroit, Michigan	165,850	138,450	995,000
Indianapolis, Indiana	79,500	61,250	625,000
Louisville, Kentucky	43,000	35,100	330,000
Saint Louis, Missouri	270,000	205,640	1,400,000
Philadelphia, Pennsylvania	700,000	377,000	1,950,000
Baltimore, Maryland	165,000	124,100	1,200,000
Washington, District of Columbia	75,000	53,400	600,000
New Orleans, Louisiana	55,000	31,530	315,000

The total yearly harvest and consumption of ice in the United States are not clearly known. They can, however, be conjectured. Twenty leading cities with a total population of 5,930,000 inhabitants consumed 3,961,000 tons of ice in the census year. Besides those 20 cities, there are exactly 200 communities in the ice belt of the country having more than about 9,000 population each, and thus large enough to warrant a local business in the cutting and sale of ice. These 200 communities have a total population of 4,510,000. The consumption in the large cities averages almost exactly $\frac{2}{3}$ of a ton of ice per head of population. In the smaller communities, the consumption would be less, owing to the greater simplicity of life and lack of industries dependent upon ice, and would average not more than about $\frac{1}{4}$ of a ton per capita, according to the best data I can obtain. This would indicate a consumption of from 1,000,000 to 1,250,000 tons per year in the 200 smaller communities referred to. In communities of less than 9,000 population there is some gathering of ice by individuals, but the aggregate in the United States would be small. Appearances indicate a total consumption of ice in the United States, in the census year, amounting to 5,000,000 to 5,250,000 tons. The harvest would be (allowing for waste) about from

7,800,000 to 8,200,000 tons. These figures are presented not as a result definitely ascertained by complete statistics, but as an estimate based upon the best information at hand, and in response to the demand for such an estimate from the persons engaged in the ice business of the country.

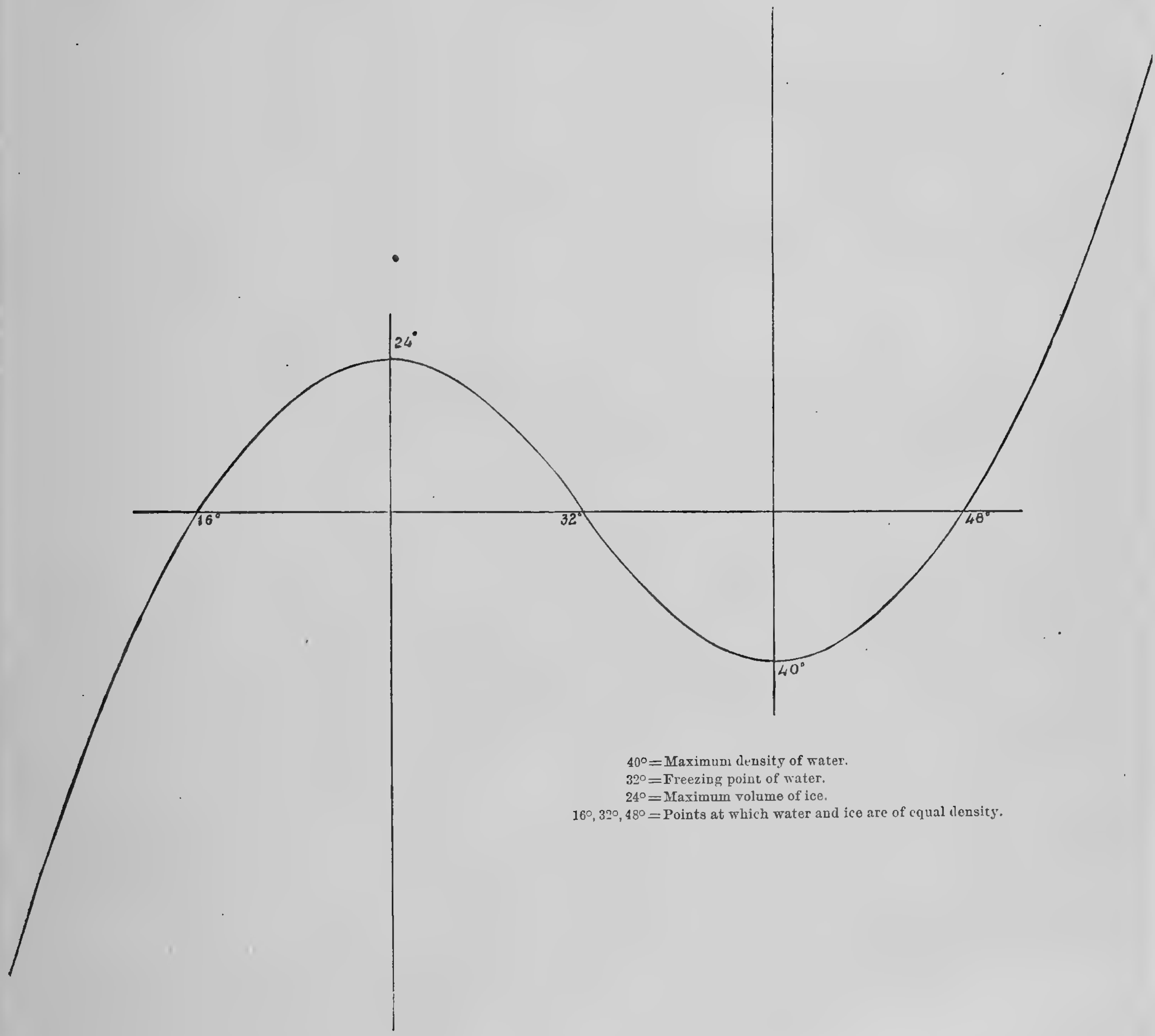
The months in which ice is usually cut are January, February, and March. Consumption takes place chiefly from May to October, both inclusive. The demand begins early or late, and is more evenly distributed through the year, according to the latitude of the city and the character of its industries. In the north 80 per cent. of the consumption is between May 15 and October 15 of each year. The following table shows the percentage of consumption by months of the several cities named, as exhibited in the returns for 1880:

Month.	Boston.	New York, Knickerbocker Ice Company.	Philadelphia, various companies.	Baltimore.	Cleveland.	Cincinnati.	Chicago.	Detroit.	Saint Louis.
January	1.9	3.5	2	2.7	1.7	8	5.5	0.2	4.4
February	1.9	4.7	2.2	3.1	1.6	3.8	3.2	0.4	10.2
March	3.1	6	2.8	7.2	3	5.5	3.1	0.6	12.7
April	3.9	9	5.1	7.6	5.8	7.8	5.5	1.3	11.8
May	11	9.4	11.4	9.2	11.8	10.3	9	3.2	8.6
June	11.7	12	13.4	12.4	13.7	12.5	11.8	14.5	11.6
July	19	18	19	17	18.5	14	16.1	32.1	14
August	17.6	12	17	14	18.5	16	15.3	30.8	13
September	13.9	10.5	13.2	10.1	16.8	14.1	12.4	11.6	9
October	9.2	8	7.3	10.4	4	5.5	8.9	2.6	2.4
November	4.4	3.5	3.8	3.6	2.9	4.4	4.2	1.9	1.3
December	2.4	3	2.8	2	1.7	3.1	5	0.8	1
	100	100	100	100	100	100	100	100	100

HARVESTING AND MANUFACTURING.

The general law of the formation of ice is that freezing takes place when the temperature of water is reduced to 32° Fahrenheit. Salt water does not freeze until it is cooled to 28°. Water does not need to be still to freeze. On the contrary, when absolutely motionless, water can be reduced to a temperature of 15° before the formation of a particle of ice, a slight agitation then, however, causing crystals to appear at once. In a lake, pond or river the whole body of water cools down to 40°, its point of maximum density, before freezing over. It has been discovered by the United States Signal Service officers that the water usually stands at that temperature for several days before the formation of ice. When the lake or river has cooled to 40°, and the atmospheric air stands at 32° or less, ice forms on the top of the water during any few hours when the surface is not ruffled by a breeze. Crystals shoot out in every direction. The interstices are filled with other crystals, until a thin film of solid ice is formed, and then by the same process the film grows thicker and thicker with each succeeding day during which the temperature of the body of air above remains below 32° Fahrenheit. The colder the weather and the steadier the freezing, the denser and clearer the ice, especially if upon the surface of a river. So that in the more northern latitudes and on the rivers, as in the states of Maine, Vermont, northern New York, Michigan, and Wisconsin, the ice is usually harder, clearer, and slower to melt than that which is formed on the southern edge of the frozen region. The hardest ice in the world, and the slowest to melt, is that formed on the tops of high mountain peaks, where it is exposed to severe and protracted cold.

It was long supposed that ice was an exception to the general rule governing the expansion and contraction of bodies near the melting point. In the light of later science it has been disclosed that the phenomena which occur in ice are characteristic of all solid substances, although in ice there is an exaggerated exhibition of it. Considering frozen water as a solid substance, its performances are strictly the same as those of other solids. When the temperature of any fusible substance is raised it expands in volume until it reaches a certain maximum point. As the temperature increases the volume contracts until a point of maximum density is reached, after which, with increased heat, the volume will expand again until the substance changes into vapor, at which point there is a further large expansion. Ice at 100° below zero is intensely hard and compact. At 16° ice is of the same volume and density as at 32°. From 16° it expands with heat until 24° is reached, when it contracts again. At 32° it melts, but still contracts in volume, until the temperature rises to 40°, when it begins to expand, and then goes on expanding almost indefinitely. True ice of 16° temperature, perfectly pure and free from all trace of air, will sink in water of more than 48°. The changes in volume near the melting point can be represented by a diagram, the curves being true parabolas, as follows:



CURVE OF CONTRACTION AND EXPANSION OF WATER NEAR THE FREEZING POINT.

The fact that ice continually changes in volume with the temperature of the weather is illustrated to those who live in the neighborhood of ponds and lakes by the continual booming of the ice during changes of weather. On a clear cold night the whole body of the ice contracts, and cracks are rent in it with such force that there is a report like the discharge of a cannon. Again, in the spring time, when the temperature is rising, the whole field of ice expands, and either shoves up on the shore with a force that cuts down trees or it lifts and breaks here and there again with a booming sound like a distant battle of artillery. Young people who are skating at night when the ice is booming are often mystified and alarmed at the phenomenon.

The waters preferred for ice-cutting are small deep lakes away from towns, where the water is pure, and rivers which are not contaminated by the drainage of towns and cities. Pond ice is apt to be full of white streaks, composed of minute bubbles of air, and the presence of air is disadvantageous, as it renders the cakes porous and liable to waste rapidly both in the ice-house and in the wagons, cars, and ships in which it is distributed. A current through a pond makes the ice better and the pond a more desirable place to cut. As a rule, the clearer and more transparent the cakes the denser and more lasting is the ice. There is no better product in the country than that which is taken from the rivers of Maine. The streams come down from forest lands and the ice usually forms on them at a temperature nearer to zero than to 32°. Opaque ice usually indicates the presence of air, but this is not always the case. When snow falls on good clear ice only a few inches thick, and there is doubt about the continuance of cold weather, the field is often sunk or overflowed by boring holes 3 or 4 feet apart, so as to admit the water to the surface of the whole field. By coming directly in contact with the cold air the mingled ice and snow quickly freeze, producing often a total thickness of cake sufficient for immediate cutting. Ice thus made is often opaque, but is not considered as necessarily inferior on that account. It shows good lasting qualities. On account of the appearance of the ice of this character, however, it is never harvested, except in emergencies. A deep lake is preferred to a shallow one, and a deep gentle river to a lake, because of there being less air in each case successively in the ice formed. There is always air in water, but in a deep lake the water cools to the freezing point more slowly than in a pond, giving the water more time to part with its air; and in a river the current carries along the minute air bubbles and to a great extent prevents them from being entangled and locked up in the crystals of the growing ice. These points were formerly not much regarded, but in the light of the experience of the last fifty years the companies now keep them in view in locating the scenes of their annual operations.

As a rule, ice-cutting in the United States takes place in the months of January and February, and in the early part of March. When ice is thick enough for operations to begin it is scraped, if covered with snow, and, if rough and wavy on the surface, is sometimes planed. When snow continues to fall the ice is often scraped from 6 to 8 times. This work is performed with machines drawn by teams of horses. There is no fixed rule as to the thickness ice must attain before being cut. It depends entirely on circumstances. On the lower boundary of the frozen belt, as for instance on the Hudson river, in Pennsylvania, Maryland, and throughout the Ohio river valley, the uncertainty of settled weather, especially if the season be late, makes it advisable to cut as soon as ice 6 inches thick is obtainable. Further north the companies usually wait for a thickness of ten or twelve inches. In Maine 15 inches is thick enough, although during the winter much ice is harvested from 20 to 30 inches in thickness. Ice sometimes forms 3 feet thick, but the cakes are then too heavy to handle economically. When the snow has been cleared away the field is "prospected" for the best point to begin cutting. Holes are bored and a measuring rod is inserted to test the thickness. The rod is marked off in inches, like a pocket rule, and the lower end is turned off at a right angle to hook on to the bottom of the ice. It pays best to cut the thickest ice, even if a smaller quantity of it be gathered; and, all other things being equal, the preference is given to that part of the field above the ice-house, if on a river, in order to gain the help of the stream in floating the detached ice down to the house. The further away from the house the cutting takes place the more the time, labor, and money required to harvest the crop, especially as the channels for floating the cakes to the house are always apt to freeze up over night, and the longer they are the more the trouble of keeping them open.

When the scene of operations has been chosen, the field is immediately lined off into squares. Two straight lines are run, as in land surveying, at right angles to each other, a surveyor's theodolite being the best instrument for the purpose. The lines are marked on the ice with the straight edge of a plank. The real work then begins The first of the ice-tools proper comes into requisition. This is the marker, an implement like a low plow, with eleven cutting teeth, one behind the other, each tooth a little longer than the one in front of it. Drawn by a horse, the marker is steered by the plow handles along the course of the straight line scratched on the ice, which it sinks at one cutting to the depth of 3 inches. The marker is then turned around, a sliding guide is placed in the line just made, and the marker is drawn back across the field again, cutting a fresh seam, 3 inches deep, at a distance of 22 inches from the first one. The guide regulates the size of the blocks, the regular width being 22 inches. When the field has been lined off in one direction a fresh set of lines is run in at right angles, dividing the whole field into squares usually of 22 inches. If the ice is thin the field is often lined off in blocks 22 by 30 inches. A favorite size for the New York market is 32 by 22 inches. In Maine and in Massachusetts the blocks are often 22 by 44 inches, and sometimes 44 by 44 for convenience in shipping to distant ports.

The next implement used is the ice-plow, the most important one connected with harvesting the crop. It is made on the same principle as the marker, except that no guide is necessary. It is constructed of six different sizes, governed by the thickness of the ice and the depth to which it can be safely and usefully cut. The sizes are respectively 6, 7, 8, 9, 10, and 12 inches, and the number of teeth varies from 5 to 8. The object of the plow is to cut the ice-field to about two-thirds the depth of the ice into cakes and blocks which can be readily detached with hand-tools and floated off to the ice-houses. The work is done by horse-power, the teams being attached to the plow with about 10 feet of tug-rope. The plow is run through the grooves cut by the marker, each passage of the plow sinking the groove 2 inches. It is run back and forth until the requisite depth is reached. A channel is then opened through the field to the ice-houses, and the process of storing begins.

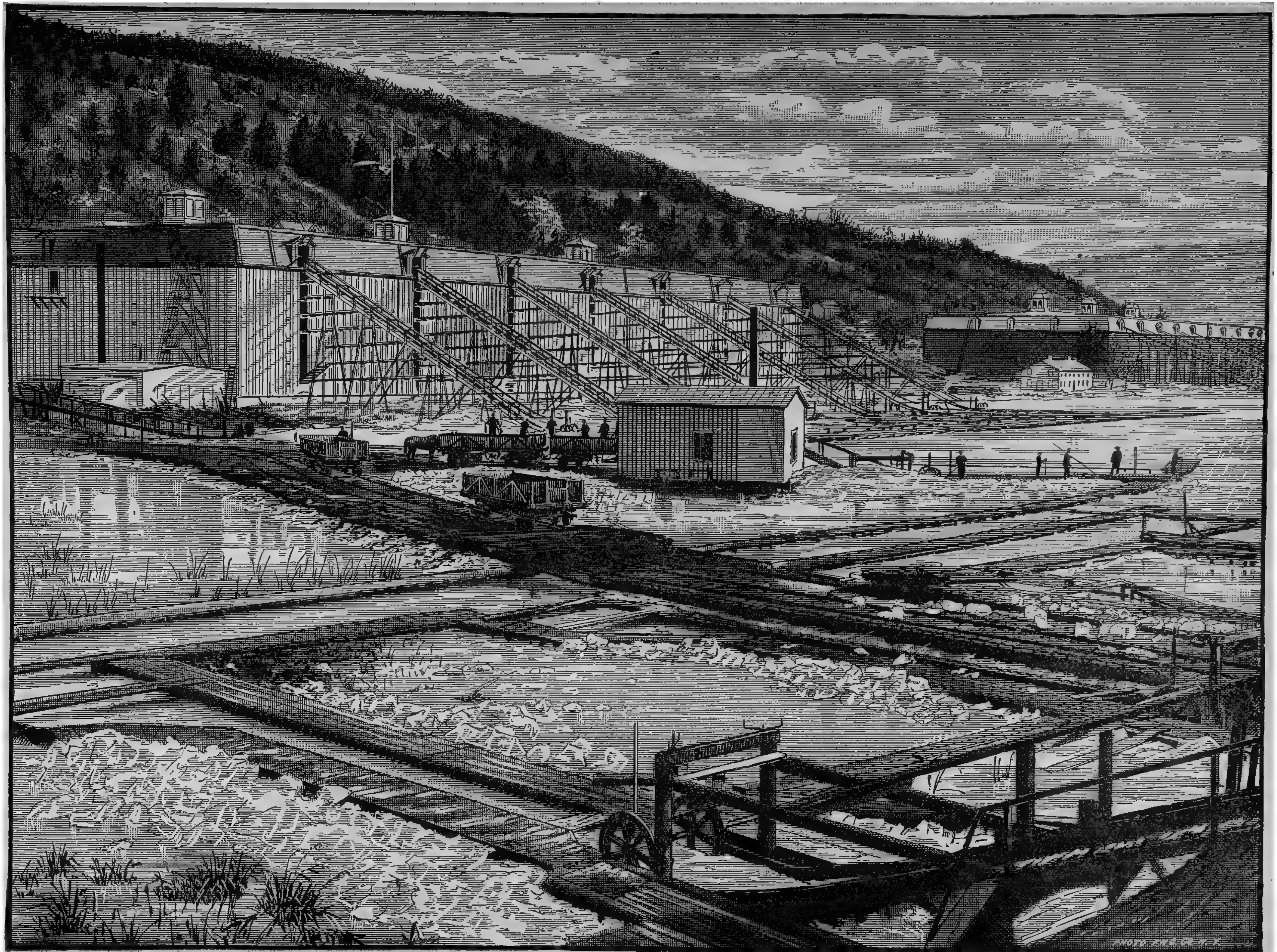
The ice next to the channel is, however, first planed by horse-power with a machine consisting of two parallel smooth blades, which run in adjoining grooves in the ice, and carry between them a knife, set, as in a carpenter's plane, to cut to any required thickness up to about 3 inches. A seat is rigged up for the man who drives the horses so that his weight may keep the plane steady in the grooves. This implement is made in the best possible manner, in all its parts, and care is especially taken to fit into it a knife of the best cast steel.

The favorite plan is to begin detaching the ice from the field at the farthest end of the channel. A steel saw, from 4 to 5 feet long, is used (sometimes a breaking-off bar or chisel), and a sheet consisting of about a dozen squares of ice is separated from the field and started down the channel. After a space has been cleared the ice is sawn off into large rafts, 12 by 30 cakes in size, which are separated into sheets on reaching the channel. The most approved plan of getting the rafts to the channel, and the sheets to the house, is by towing them with a team of horses, or even with a single horse; but sometimes an ice-cutter will walk out on the floating raft and pole it along to its destination with a tool called a hook, consisting of a long, light wooden handle, fitting at its extreme end with a spike on one side for pushing and a hook on the other for pulling. Sometimes the channel is lined with men armed with hooks, who pole the detached pieces along without leaving the main field. When horses are the motive power a tow-line is used having a grapple which catches the after end of the sheet. When the floats arrive at the ice-house they are separated by light breaking-off bars, either into single cakes or into squares of four cakes each, for hoisting into the house and stowing away. It is a common practice with firms owning large houses to make plank walks or landings out along the sides of the channel near the shore, and at the foot of the inclined planes, for the ice-men to stand upon while wielding the tools by whose aid the ice is separated into cakes and pushed along to the planes.

The house into which the cakes are now hoisted is quite a different affair from the covered pit or cellar, or the hill-side cave of from sixty to eighty years ago. It is sometimes of brick, but usually of wood—a large, barn-like structure, planted at the edge of the pond, lake, or river, in a location which is dry and well exposed to the sunlight and air, and where also it is readily accessible by barge or schooner, if its contents are destined for shipment to distant markets. Damp localities are avoided. One of the worst enemies of ice is moisture. The outside of the house is painted, or whitewashed, a glaring white, to reflect as much as possible the rays of the sun in summer; and the walls and space under the rafters are so arranged as to be almost impervious to the heat of the outer air. These long white buildings are conspicuous objects in the landscapes of the Hudson and Kennebec rivers. The size of the house is governed in part by the producing capacity of the body of water at whose edge it stands, and in part by the magnitude of its owners' business. It is usual to divide the houses into "rooms" from 30 to 35 feet square, each holding about 700 tons of ice, the rooms being 30 feet high, and a ton occupying 42½ to 45 cubic feet of space. Rooms are often large enough, however, especially in Maine, where three or four are thrown into one, to hold from 2,500 to 3,000 tons of ice. In a few cases a room has been made to hold from 4,000 to 5,000 tons. A medium-sized house is one which will store 10,000 tons. A large one will accommodate 60,000 tons. As ice will waste from 10 to 25 per cent. in an ordinary house, especially after it is opened, and as there is a total waste in all of 40 to 55 per cent. before reaching the consumers, it is usual to build with a capacity a third larger than the quantity which is expected to be sold in the course of the year. The cheapest lumber that can be bought is usually employed in construction. Spruce, hemlock, and white pine are the favorite woods, with pitch pine for sills, and hard wood in the main rafters. The roof is shingled with cedar, or some other good quality of shingle. About 175,000 feet of lumber are required for a 10,000-ton house. The frame of the house is erected after the usual fashion of frame buildings, and is generally of spruce, where it can be had. It is boarded up inside with hemlock, and outside with white pine, the spaces between forming an air-chamber clear around the house, which, when ventilated as it ought to be, keeps the house dry. In the majority of houses the frame is not sided up outside at all; but experience has led, especially in the warmer localities, to the boarding up of both sides of the frame, and the practice is a growing one. The roof is built in such manner as to have plenty of loft room. On the side of the house toward the water there is a doorway in each room, extending clear from the eaves to the foundation. As the house is filled with ice this doorway is closed up, five or six feet at a time, until it is sealed clear to the eaves. Preparation is made for stowing away the ice by packing the walls of the house. Light studs, about 3 by 8 inches in thickness, are placed against the matched hemlock or pine boarding, which covers the frame of the building, and these studs are in turn boarded up to the eaves with matched stuff. In the best houses felt or manila paper is tacked over the studs, before the boards are put on, as an additional safeguard. The space between the studs is then filled with dry

sawdust, charcoal, shavings, or any other non-conducting clean refuse that is easily obtainable. The floors are of earth, covered with charcoal or sawdust, and then boarded over. Proper drains are made across the floor of the building to carry off the drip from the store of ice. A narrow inclined plane is next built from each room into the lake or river for hoisting the ice into the house. The proper angle of pitch is from 40° to 45°. The inclined planes are simply, but stoutly, made, with strong side timbers, secured to each other by cross-pieces, which are floored over with battens, the spaces between the battens allowing the water to drip from the cakes of ice to the ground below as they come up the plane. The battens are sometimes faced with strap iron. The elevating is done by an endless chain driven by steam-power. This chain carries a series of wooden hold-bars, or buckets, whose mission is to catch the cakes of ice, one by one, as they are poled up to the inclined plane in the channel below, and draw them steadily and swiftly up the plane until they reach the proper point for delivery into the house. Every five or six feet in height from the ground there is a delivery run, or shoot, built like the inclined plane, open, leading from the plane into the house, and these are made use of, in turn, one after the other, as the rooms fill up, until the last one is reached at the top. The runs are usually iron on the face of the battens.

Two systems of elevator-chain are in use, the overshot and the undershot. In the overshot, the chain carrying the hold-bars moves up the inclined plane, then over a wheel, and down perpendicularly to the ground, and thence horizontally to the water. In the undershot, the chain returns to the water down the top of the railing of the inclined plane. Both systems have their advocates. Driven by an engine of about 20 horse-power, these elevators have a capacity of raising about 175 tons of 12-inch ice an hour, which is as fast as one man can feed from the channel and 20 men stow away in the house. The chain moves at the rate of 100 to 110 feet per minute. When speeded, and when the ice is thicker than 12 inches, from 400 to 500 tons can be raised in an hour; but, in that case, a large force of men would be required to feed and stow away. The ice is packed away in the house in regular layers, the cakes being kept slightly apart, both to allow the water in melting to run away, and also to prevent the cakes from freezing into a solid mass. Near the top of the house, they can be placed in direct contact. When the house is full, the loft under the roof is filled with hay to protect the store from the heat of the sun in summer. It is surprising how long ice will keep in a house properly built, packed, drained, and ventilated, into which the ice has been put hard and dry, and which is closed for the season in freezing weather. There is always some waste, amounting at times to from 10 to 25 per cent.; but in a first-class house, in which attention has been paid to every detail, ice will keep for two or three years, with no more waste than that during the whole period. It may be mentioned incidentally that the cost of wooden ice-houses, with machinery, is from 75 cents to $1 per ton of capacity, according to the local abundance of timber and rate of wages. The cost of brick houses, with machinery, is about $2 per ton of capacity.



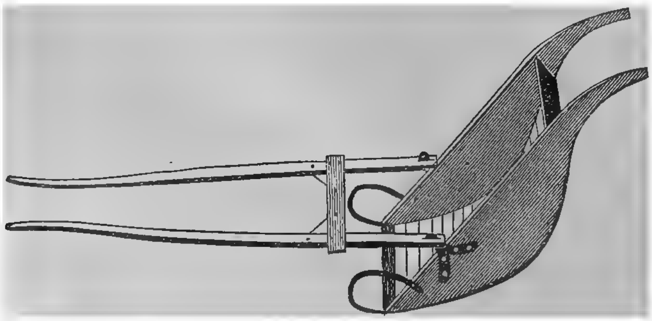
ICE CUTTING ON THE HUDSON.

Returning now to the ice pond: The ice was left floating in the channel, broken into cakes of the right size for storing. The steam-engine propelling the elevator apparatus is started, the engine being generally placed in a shed at the foot of the ice-house. One or two men pole along the cakes to the inclined plane, where they are caught in succession by the hold-bars and carried up to a trap which admits them to the first shoot or delivery runs leading into the house. This shoot is set at a slight pitch toward the house, and the heavy cakes slide down with great rapidity, one after another, covering the floor of the room in every direction. A force of men inside quickly catch them with pole-hooks and arrange them in regular array until they cover the floor. Another tier is then made, and another, until the height of the shoot is reached. Operations are stopped long enough to close the trap at the entrance of the shoot. The trap leading to the next shoot above is opened; and the process is repeated until the house is full. As already indicated above, a smart man or two feeding the cakes upon the elevator will keep from 15 to 20 men busy inside one room, stowing them away; and to keep them all busy will require about 100 men with 10 or 12 teams of horses, at work out on the pond scraping, plowing, and breaking up the field.

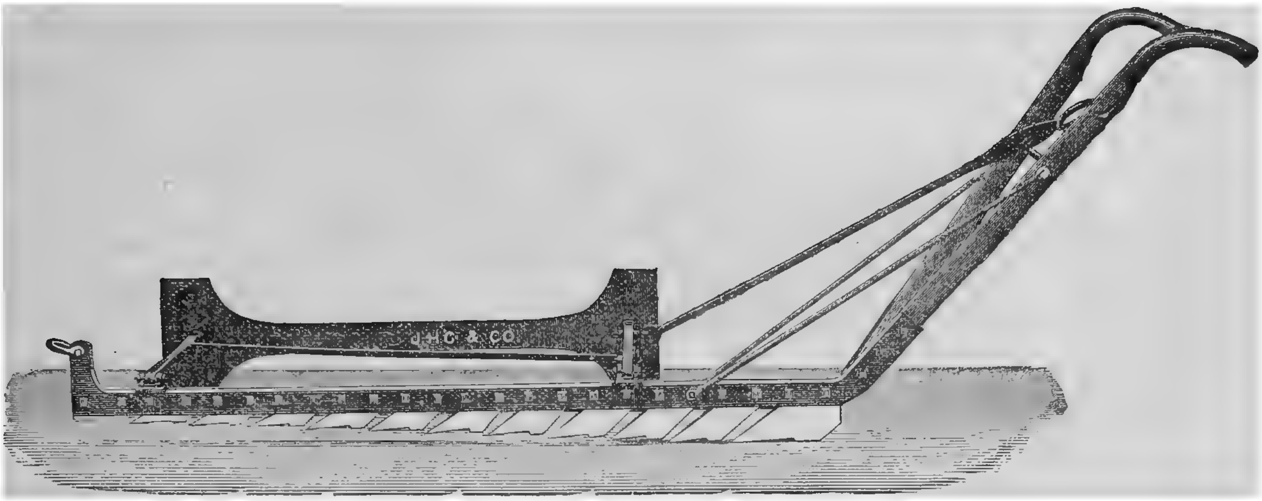
One of the important details of work out on the pond is to take care that water does not flow into the grooves cut with the plow when a raft is detached. In freezing weather all the work of the plow would be undone, if that were permitted. To prevent it, calking irons (long bars fashioned at one end into a chisel) are used to stop up the ends of the grooves with ice chips. Another matter requiring attention is keeping the channels to the house open over night. Each ice man has his own plan for accomplishing this result. Some clear the channels of all the refuse ice at night and leave them full of new sheets to be towed to the house in the morning; they can be easily broken out and sent along. Sometimes the men turn the sheets over before leaving them, so as to prevent the grooves in them from filling with water and freezing. Some foremen leave no ice in the channels at all at night, but run the risk of their freezing over, and then set their whole force at work in the morning for an hour or two clearing out the channels for the resumption of operations. Sometimes the channel is kept open by towing a block of ice back and forth all night. Another feature of work on the pond now is the rapidity with which business is pushed after cutting has begun. The reasons for haste are the liability of the open water to freeze over, the danger of changes of the weather, especially of rains, and the general economy of quick work. It is not unusual in the states, where the ice is thin and liable to be spoiled by a change of weather, to rush matters so fast as to fill the houses in from six to twelve days. In the regions where severe and settled weather can be depended upon the crop is usually harvested in from fifteen to thirty days. In all cases, however, it is the practice to push the work with energy. The employment of a large force of men is accordingly called for. To fill a 25,000 ton ice-house, about 100 men with 10 or 12 teams are ordinarily engaged, and sometimes about double the number. After the house is filled the ice is covered with sawdust and the house is closed up as before stated.

The tools now used by the ice-men show a remarkable appliance of inventive genius. The pioneer ice-cutters had nothing except the ax and a large cross-cut hand-saw. With such simple implements they were a long time in harvesting even a small quantity of ice; and when they had brought it ashore they were without convenient facilities for transferring it to the storage-house. For fifteen or twenty years a great many new implements were experimented with. Some were failures. Many had merit. Plows were finally thought of. They were at first made with wooden beams, the teeth being iron, tipped with steel, and widened or upset at the points. One alteration after another was made in the plow. Chip spaces were cut in the narrow teeth, so as to let the plow run to its full depth in the groove, leaving only the heel and toe of each tooth to be filed. Improvements were made in the curves of the teeth, and plows were then made of solid iron and steel. The patent clearing-tooth was invented as late as 1872. Among the devices brought out was a patent gig or light wooden frame, swung on a rope and pulley for elevating ice into the house or transferring it from car to ship. Previously the only means was the common pulley and rope and a pair of tongs, worked by horse-power. Both devices have since been nearly superseded by the endless-chain elevator, worked by either steam- or horse-power. The endless chain has also been applied within a few years to the handling of ice on wharves, especially in Philadelphia, where the blocks of ice taken out of vessels are carried along the wharf by the chain and buckets and up an inclined plane into the store-house. Leaving aside the machinery for elevating ice, the ice-tools of the present day are 60 in number. The majority of them are used at the ice-pond, the rest by the retail dealers in distributing ice to consumers. The principal tools are the following:

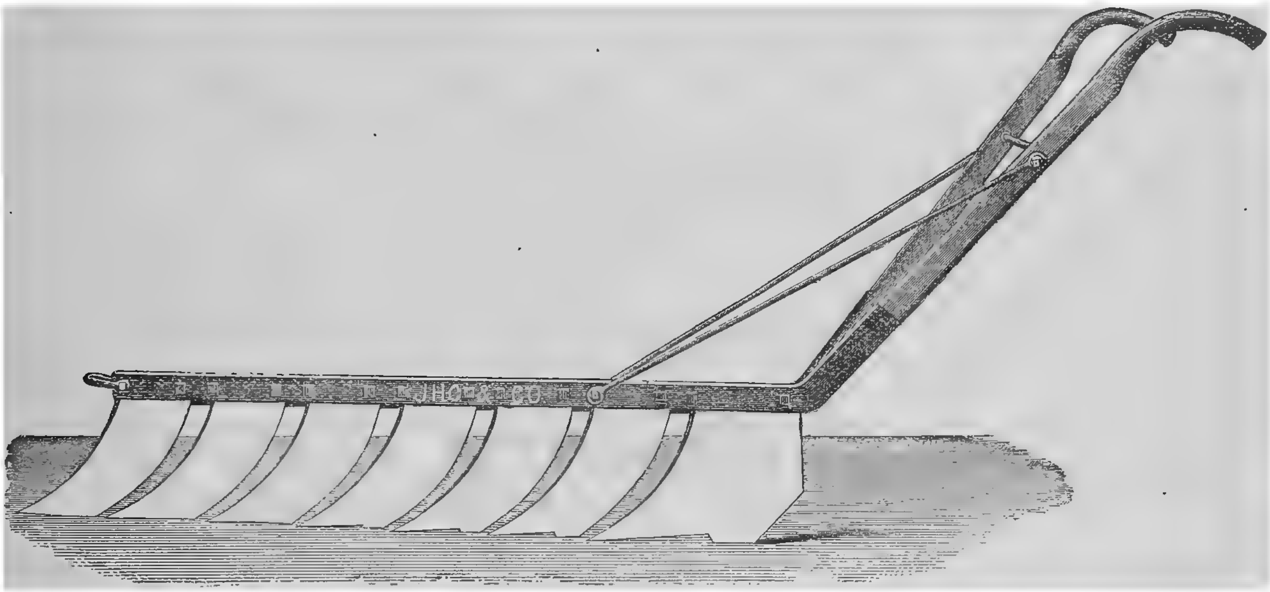
1. Scrapers for clearing away the snow; 2 styles.



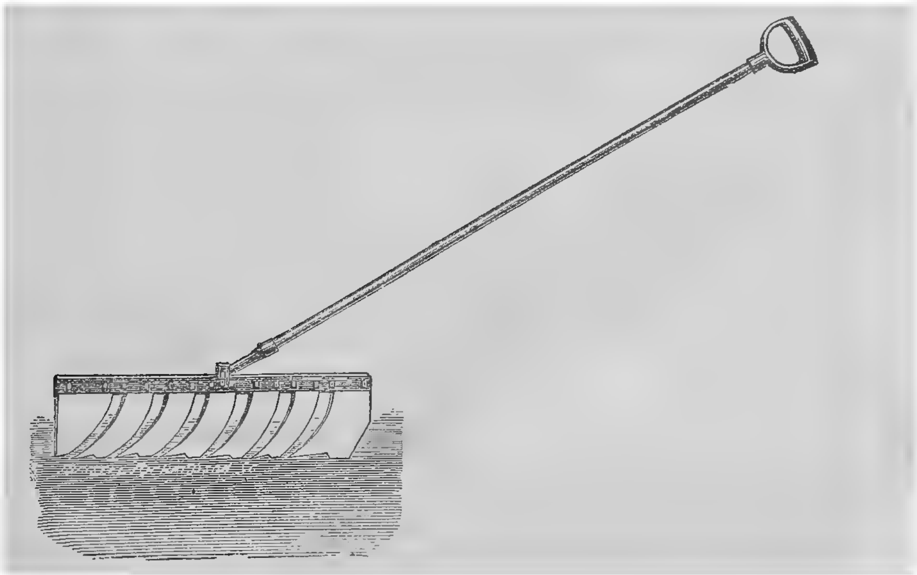
2. Cast-steel ice-marker with swinging guide.



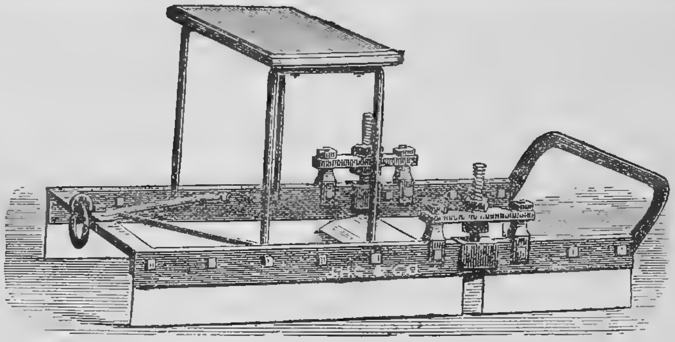
3. Ice-plow, cast-steel, made of various sizes, with 5, 6, 7, and 8 cutting-teeth, to cut anywhere from 6 to 12 inches deep.



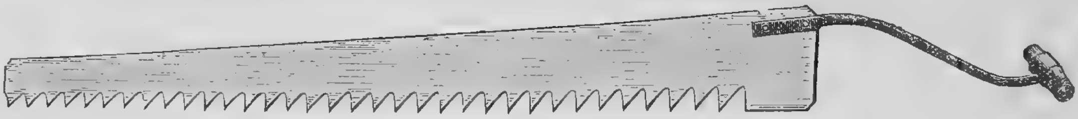
4. Hand ice-plow, 6 inch.



5. Ice-plane.

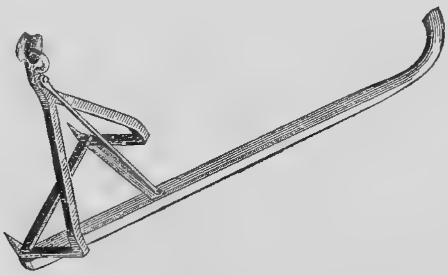


6. Ice-saw, for opening channels and separating the rafts and sheets from the field; also used by small firms who cut without the aid of a plow.



7. Grapple, for towing rafts and sheets by horse power along the channels, and also used for hauling blocks up the inclined plane by horse-power when no endless chain is used.

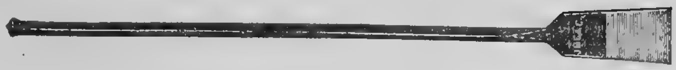
8. Jack-grapple, used for the same purposes as the last.



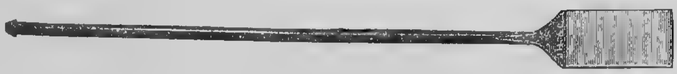
9. Breaking-off bar, the ice-cutter's handy tool; the broad blade is for detaching large sheets, the small blade for splitting off the smaller blocks.

10. Calking-bar, for filling the grooves in the ice with snow or chips to prevent the flooding and freezing up of the grooves.

11. Bar or packing-chisel, for loosening and trimming cakes.

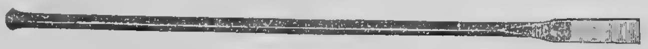


12. House-bar, for separating the smaller cakes from each other.



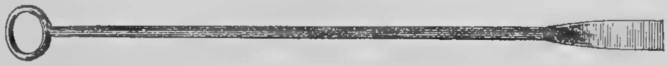
13. Fork-bar; a tool coming into use in place of the breaking-off bar.

14. Splitting-chisel; a light serviceable tool for separating the sheets into cakes.



15. Canal-chisel; the same as the last, except longer; for use when the operator stands on a raised platform.

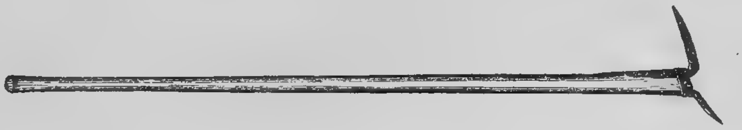
16. Ring-handle chisel; useful in cutting holes in the ice to flood the field, the ring preventing the tool from ipping from the operator's hand and being lost.



17. Floor-chisel, much used in storing ice, for trimming the blocks.

18. Starting-chisel, or curved tool, for loosening up the blocks in the house one from the other.

19. Ice-hook, a light, handy, and indispensible tool for pulling and shoving cakes of ice, having handles from om 4 to 10 feet long.



20. Float-hook; the same as the last, except that the handles are from 12 to 16 feet long.

21. Line-marker, for cutting a groove for the ice-marker to follow.

22. Hook-chisel, for splitting blocks of ice, and for handling them on the elevator.

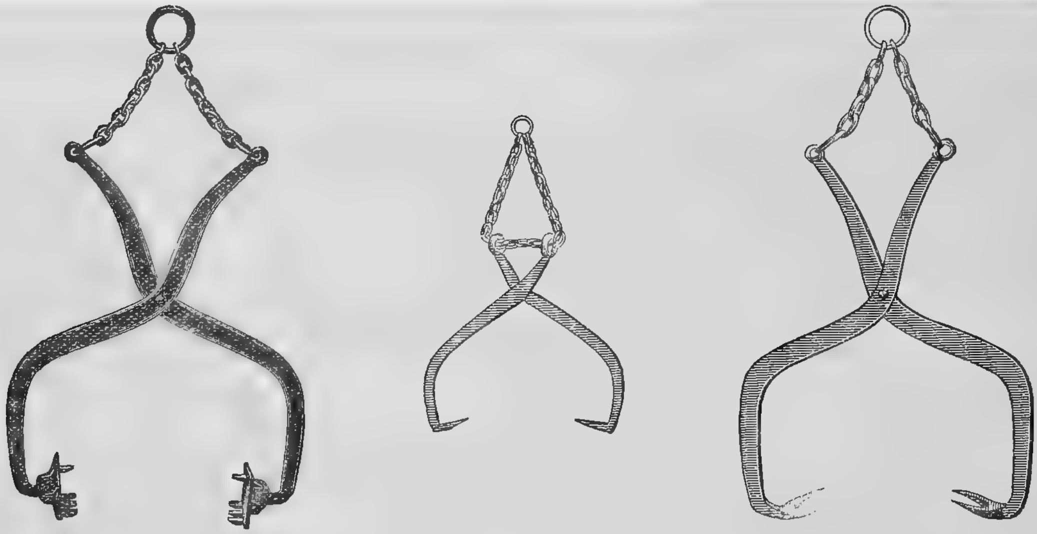
23. Scoop-net, for clearing the channels of broken ice; the net made of light chains.

24. Elevator-fork, used in place of an ice-hook for feeding ice to the elevator.

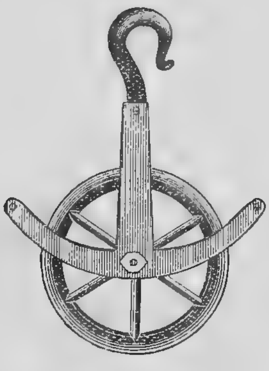
25. Ice-auger, for boring holes to test the thickness of the ice.

26. Measuring rod, for testing the thickness of the ice.

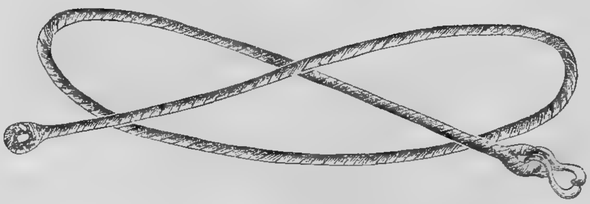
27. Hoisting-tongs, for hauling blocks up the inclined plane, and for loading and unloading vessels; in three patterns.



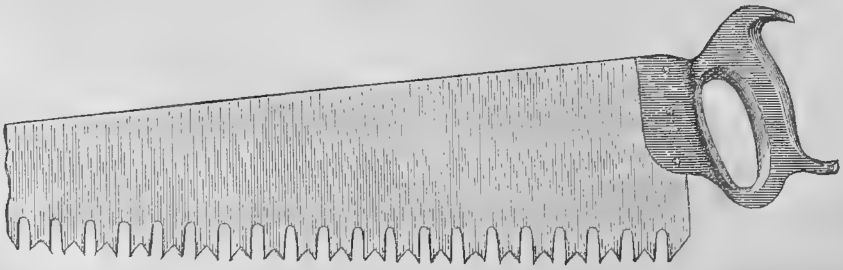
28. Hoisting-gin, used in place of a wooden pulley when the house is filled by horse-power.



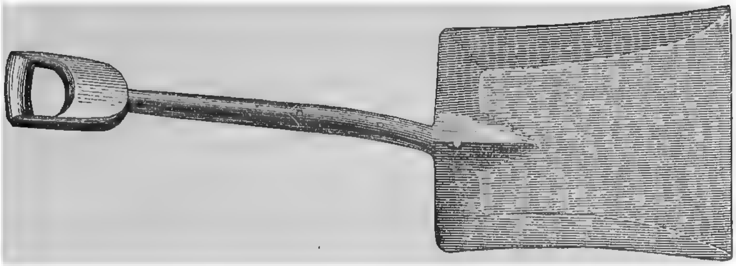
29. Plow-rope, 10 feet long, of 3-inch manilla cordage.



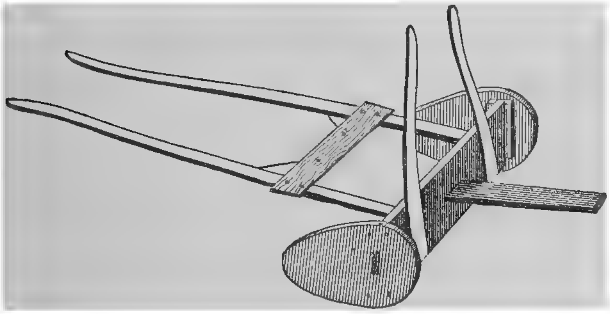
30. Hand-saw for cutting blocks into smaller pieces.



31. Snow-shovel, for handling sawdust, snow, broken ice, etc.



The tools not specified above are principally small implements used in the sale of ice, such as axes, forks, picks, scales, etc. For a moderate business in ice-cutting, as, for instance, the filling of one or two houses, an



outfit of tools will cost from $500 to $1,000. The large companies, however, often have $10,000 invested in these implements. The thousand-dollar outfit would include 10 scrapers, 2 markers, 6 plows, 6 hand-plows, 2 planers, 4 saws, about 45 bars and chisels of the different patterns, about 100 ice-hooks, 24 float-hooks, 4 scoop-nets, 4 elevator-forks, an auger, a measuring-rod, 4 pairs of tongs, and about 4 hoisting-gins.

Experiments have been made during the last ten years with an implement, which has not, as yet, been made a success. This is a circular saw, driven by steam-power, for sawing out the ice from the field. So far, no machine has been produced light and handy enough to work with to advantage out on the pond.

In transporting the crop to market resort is had to railway cars or to ships and river boats, according to the location of the houses. In Maine, whose ice is cut principally for transportation to markets beyond the limits of the state, the loading is done on three-masted schooners and barks, and a few medium-sized ships, which have survived their usefulness for the carriage of finer commodities. Sawdust, shavings, marsh hay, and cheap lumber are used for dunnage, and the hold is closely sealed up until the arrival of the vessel at its destination. To Boston the ice is brought down from the ponds in railway cars to depots on the wharves. It is then transferred to schooner for the southern and West Indies trades, and to larger vessels for shipment to more distant ports.

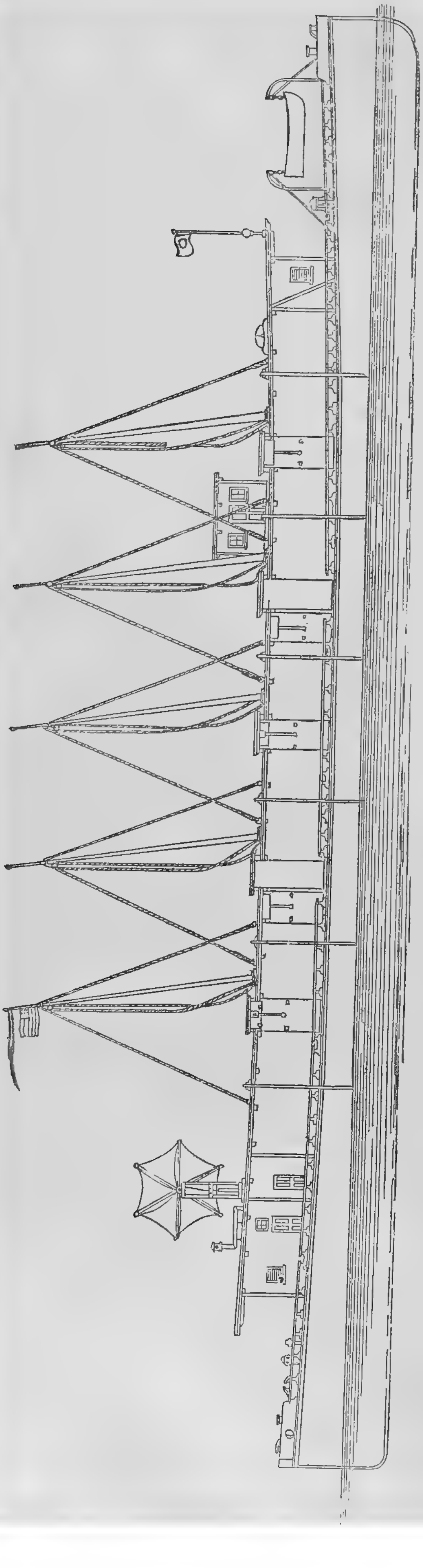
On the Hudson a large fleet of barges, built especially for the trade, are employed. There are about 100 of them at present. They vary from 110 feet in length, 26 feet beam, and 9 feet in depth, registering 325 tons, to boats 140 feet long, 34 feet beam, and 10 feet in depth of hold, registering 750 tons. They carry from 400 to 1,100 tons of ice. The barges are built with white oak frames, are planked and decked with yellow pine, and housed with white pine. The hulls are alike at both ends, rather bluff, flat on the floors, and in general bulky and capacious. A cargo-house covers about three-quarters of the length of the deck. The cargo is stowed both in the hold and in the house.

In the side of the cargo-house there are from three to five doorways which, in the form of hatchways, are extended part way across the roof. Masts extend about 30 feet above the top of the house, raking so that their tops are each over a hatchway. They are used for derricks in loading and discharging cargo. A small windmill revolves above the top of the roof, and drives a pump for clearing the hold of water from the melting ice. The barges are made up in fleets of from 6 to 12, and are towed to New York by a harbor tug. The building and repairing of these boats make much work for the shipyards of the Hudson.

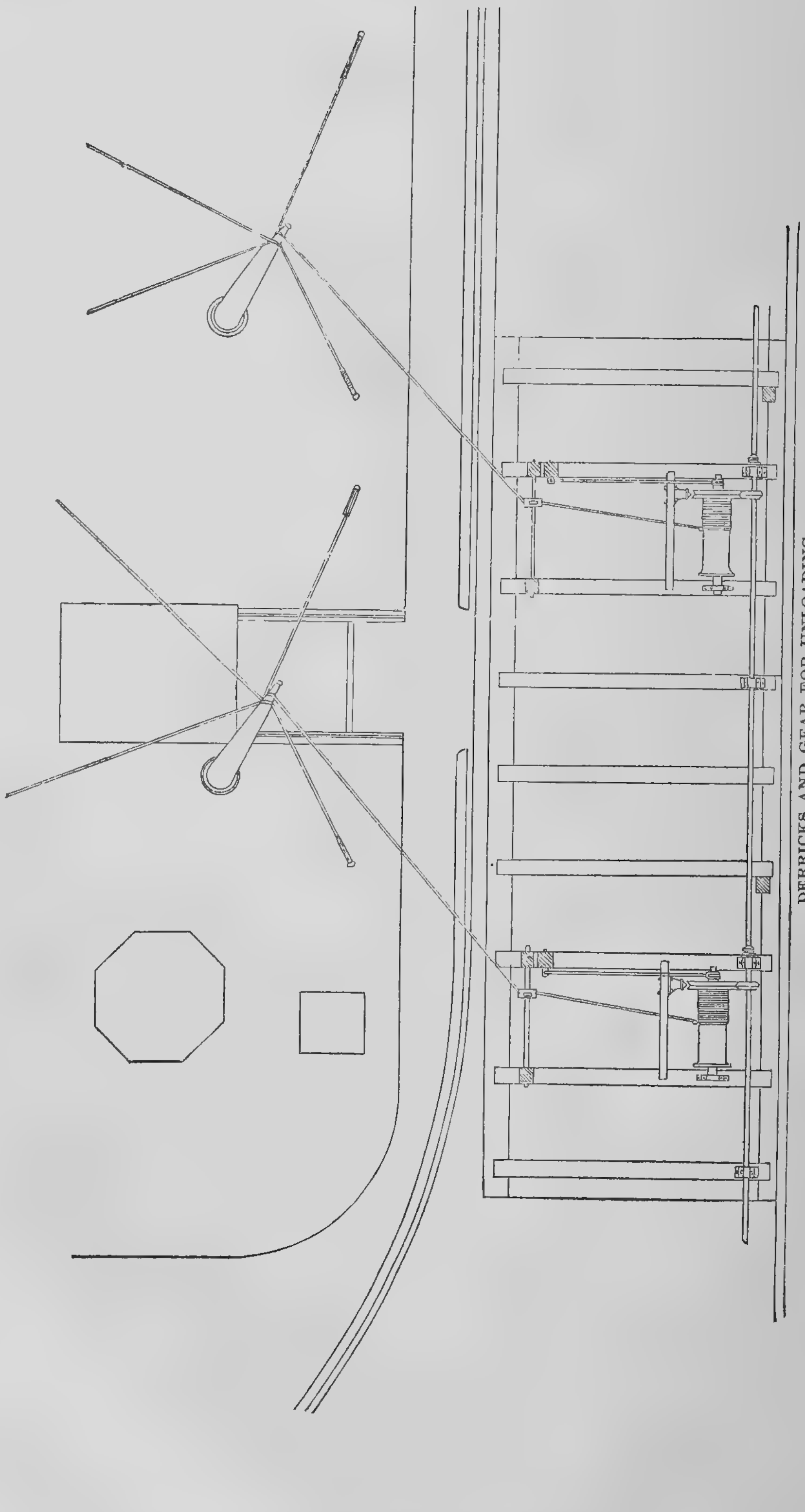
The Knickerbocker Ice Company unloads its barges at some of its large depots by steam-power. A line of shafting on the wharf works a drum around which is coiled the end of the rope used in hoisting the blocks out of the boat. The drum can be thrown into and out of gear as occasion requires. The ground plan of this invention is shown in the illustration.

On the upper Mississippi ice is despatched to market both by railway car and by river barges, the latter carrying up to 1,200 tons each.

The production of cold by artificial means began at a much earlier date than is commonly supposed. In India, Arabia, China, Egypt, and other eastern countries, porous earthern vessels were used for keeping water cool by the agency of evaporation from the surface of the vessels; and it has already been told on a preceding page how



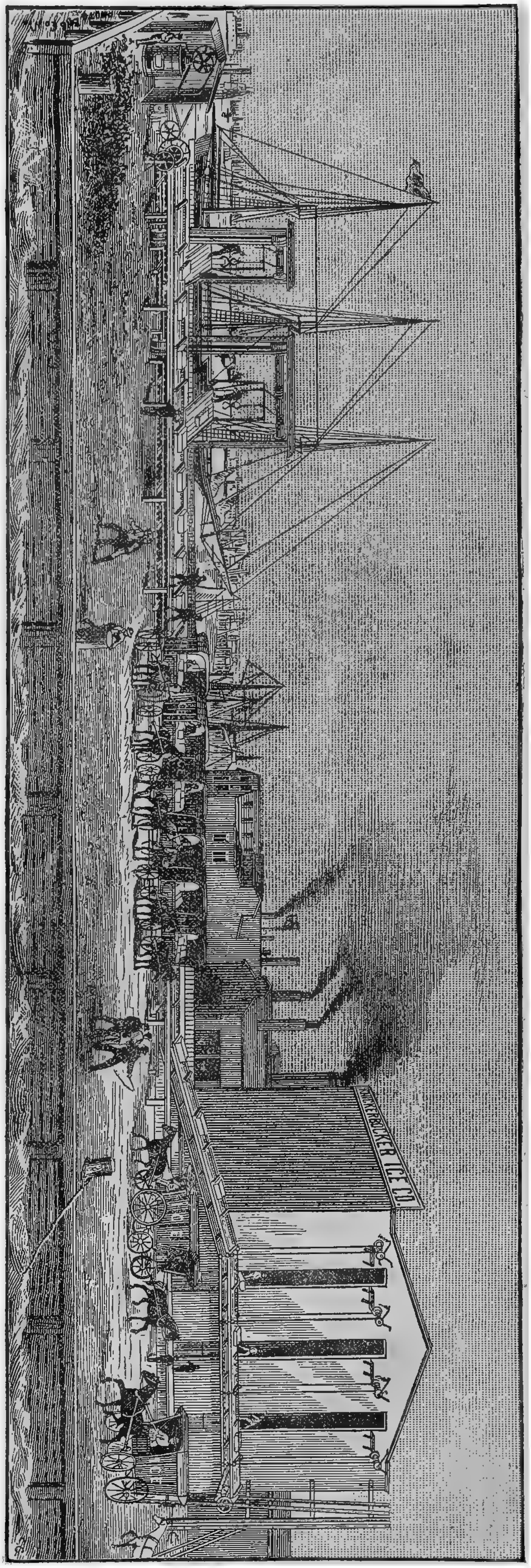
ICE-BARGE.



DERRICKS AND GEAR FOR UNLOADING.

the same idea was applied in very ancient times for the production of ice itself. Wine bottles were kept cool by wrapping them in wet cloths, handsomely ornamented when the bottles were in actual use on the table. After snow and ice came into popularity a simple cooling mixture was made by adding salt to those substances. The salt hastened their melting and extracted the heat of the bodies to be cooled more rapidly than either snow or ice would do it alone. Ether was also known at a very early date to produce cold by evaporation. In India, owing to the cheapness of niter, it has been common to use a solution of niter and water as a cooling mixture for wine. The record of definite attempts to produce freezing mixtures in a scientific manner begins with the Italians in the sixteenth century. Lord Bacon took much interest in the experiments made in his time; and in 1795, as a result of the studies of Mr. Walker, of Oxford, England, a number of tables of freezing mixtures were printed in the Philosophical Transactions of that year. Professor Leslie, of England, produced a considerable degree of refrigeration on the principle of exposing in the exhausted receiver of an air-pump sulphuric acid, a substance rapidly absorbing vapor. The problem of freezing by artificial means interested a great many minds at the same time, both in England and on the continent. Among other plans tried was the purely mechanical one of placing a quantity of water in the receiver of an air-pump and exhausting the air by powerful machinery, the slow evaporation of the water producing cold intense enough for the purpose. In 1834 an American in London, Jacob Perkins, patented a machine for ice-making, by the evaporation of sulphuric ether under an air-pump. The machine was afterwards improved by Professor Twining, of New Haven (1850); Harrison, of Australia (1857); Siebe, of London (1862); and later by Siddeley and Mackay, of Liverpool and London. When attention had been briefly turned to the use of volatile substances other liquids than ether were sought for; and during the last forty years a great many experiments have been made with a wide range of substances. The French have been especially active and ingenious in this field of research, and the name of their leading inventor, Carré, is now indissolubly connected with the successful application of the idea of evaporating a volatile fluid for the making of excellent and inexpensive ice. Among the new experiments made were those with ammonia, methylic ether, sulphurous acid, bisulphide of carbon, naphtha, and gasoline, or chimogene. Incidentally during the study of this subject some remarkable results were obtained. By the evaporation of sulphurous acid the temperature of 100° Fahrenheit below zero has been produced, and carbonic acid gas converted into a liquid, by the evaporation of which, in turn, the so-called permanent gases have been converted, under pressure, into liquids. Time and experiment have eliminated many of the substances above referred to from use; and the practical ice-machines of the present day employ only ammonia,

WHARF WITH ENDLESS CHAIN AND APPARATUS FOR TRANSFERRING ICE FROM SCHOONERS TO THE ICE-HOUSE.



There are now about forty different styles of ice-machines in operation in different parts of the world. Nearly a hundred have been patented at Washington. Not over half a dozen, however, are in this country considered of much practical value at the present time. The machines are all the same in principle, though various in construction. The principle is that a liquid in changing its form to a vapor abstracts heat from all surrounding substances; the more rapid the evaporation the more intense being the cold produced. The chief troubles the inventors have encountered have been the danger of explosion, to which the ether machine is especially liable; the leakage of the gases through the joints and pumps, which, by diminishing the pressure within, destroys the efficiency of the machine; the fact that an invention which will work successfully in a northern climate sometimes proves a failure in a warmer region, and the frequent great cost of operation. In order to carry on a successful business in artificial ice-making the product must be manufactured at a cost of not to exceed $2 or $3 a ton. The chief cause of the numerous disastrous failures so far has been that the product cost anywhere from $20 to $250 a ton. One American proprietor lost $100,000 in experiments at New Orleans before success was achieved. It has been the aim of inventors in this country to make ice at from 75 cents to $1 per ton. Many times during the last ten years the announcement has been made that the result has been accomplished. It is doubtful if, in practice, any ice-maker in America has yet been able to produce ice so cheaply; but the cost has, nevertheless, been reduced at length to a point where the making of ice is commercially practicable, and it is now carried on as a regular industry in a large number of southern cities in competition with the importation of natural ice from the north.

The process of ice-making is substantially the same in all machines, and a description of the way the thing is done by the Louisiana Ice Manufacturing Company of New Orleans will give a correct notion of it. The substance employed for evaporation is ammonia. In its uncombined form ammonia is a gas, having a remarkable affinity for water. A compound of water and ammonia is placed in an iron retort, or boiler, the fluid being deep enough to cover a coil of pipe in the bottom of the retort, occupying about one-third of its capacity. A current of steam is sent through this coil to heat the water to from 130° to 150°, and to volatilize the ammonia. The heat disengages the gas, which rises into the top of the retort, and is carried off into a series of pipes in a square box, called the "liquefactor." Cold water circulates in a constant current around the pipes of the liquefactor, and the gas condenses to a liquid under the influences of the refrigeration it receives and the pressure of the new gas which is continually coming. The liquid ammonia flows into a reservoir below called the "recipient" until a sufficient quantity has accumulated to begin the work of making ice. It is the return of this liquid to its gaseous form, or, in other words, its evaporation when pressure is removed, that generates the ice. A stopcock is opened which allows the ammonia to flow from the recipient into and through a network of pipes which fill the interior of a large tank called the "refrigerator." Finding room for expansion, the ammonia rushes into the pipes, vaporizes, absorbs heat in the process from the salt water surrounding the pipes, and rapidly reduces the temperature of the brine much below the freezing point. The brine, thus suddenly cooled, in turn absorbs heat from shallow pans of fresh water which are suspended in the refrigerator, and the fresh water is converted into blocks of solid ice. If this were the end of the process ice-making would be too expensive for commercial success. But so far only one-half of the business of the machine has been performed. The next step is to recover the gaseous ammonia for use a second time. When the ammonia was volatilized in the retort by heat a great pressure was generated. The water was forced back out of the bottom of the retort through a tube into an exchange or drum near by, and thence into a cooler, and still on into a "vase of absorption." Here the cooled water meets the gaseous ammonia, which has gone on through the refrigerator and has been conducted through tubes to the vase of absorption. The ammonia combines by affinity with the water again, forming a new saturated solution, and this is pumped back into the retort to undergo another operation. The gas is thus used over and over again. It is this part of the process which secures the economy of ice-making. This machine will make an average of 18 to 19 tons of ice a day, or about 5,500 tons a year.

Another variety of ammonia machine is used by the New Orleans Ice Manufacturing Company. It is the California invention of Mr. Beath. The principle is in all respects the same, but the ice is made not by freezing it in pans, but allowing it to form on the pipes of the refrigerating tank. The pipes are vertical, 32 feet high, placed in rows 4 feet apart one way, and 2 feet apart the other. When the liquid ammonia is allowed to enter them and evaporate into gas, water is showered upon the pipes and the ice forms on their surface, growing continually in thickness as long as evaporation continues. Water is thrown upon the pipes greatly in excess of the quantity that can be frozen. The result is that any solid substances contained in the water are washed down by the current, and thus the muddy water of the Mississippi river yields a pure and brilliant ice. The columns of ice around the pipes grow in diameter until they meet. They finally become transformed into perpendicular walls of solid ice, 32 feet high, and about 3 feet thick. Freezing is then stopped; gaseous ammonia is forced back into the pipes under pressure. Under compression heat is given out and the ice is melted away from immediate contact with the pipes. Horizontal and vertical grooves are then cut in the walls of ice and the blocks are split out and carried away for consumption. The house of the New Orleans company is large enough to hold 10,000 tons of ice. It is divided into four compartments, in which the vertical iron pipes are erected. In the winter of 1882-'83, with only half its apparatus in use, the product was 50 tons a day.

Other machines have been tried in America, in which sulphurous acid and other liquids have been volatilized by creating a vacuum with a powerful pump, the liquid afterward being condensed under pressure. Two of the

Roach line of steamers to Brazil were supplied with refrigerating apparatus of this class. The work done did not yield satisfactory results, and the machines were taken out. Inventions of this class are being used, however, in various parts of the United States.

Within a few years a class of machines has been brought out, intended not for the manufacture of ice, but for the refrigeration of storage rooms by cooling the air. They are ammonia machines, as a rule, and in large establishments have been found to give satisfaction. They have been introduced to breweries in large numbers within the last five years. There are those who now predict their universal adoption by brewers within the next ten years, at least by all the large firms. It will be cheaper for the smaller firms to buy natural ice. A year of short supply and high prices tends to increase greatly the number of machines in the breweries of the large firms.

THE INDUSTRY IN THE SEVERAL STATES.

In the following notes no effort has been made to cover the whole industry throughout the United States. Only the general facts about the business in the principal regions of production have been collected. So far as these regions are concerned, inquiry has not been confined exclusively to the matter of the supply required for special cities, but a conscientious attempt has been made to give a fair picture of the whole production of each region. Some historical notes of each special locality have been added where possible.

MAINE.

The rivers of Maine are famous for the purity of their water. They rise in the depths of the forests, often flowing from crystal lakes, and their banks are free from large cities and manufacturing establishments to contaminate the current. Sawdust is about the only refuse of any account that finds its way into most of them. Their beds are deep. To add to their value as waters for the harvesting of ice, they nearly all flow with a strong current, which secures clearness and purity in the ice. The winters in Maine are severe, lasting long and freezing steadily, which is again an advantage. It is not necessary to harvest the annual crop with the feverish hurry of warmer states, and the ice itself is the denser and thicker for the long continuance of the cold weather. Of all the states, Maine is the most favored by nature for the ice business; and though the consumption of ice locally is small, owing to the coolness of her summers, yet Maine now stands first in the list of the ice-gathering states. Nine-tenths of the product is sent to other localities for consumption, chiefly to New York, Philadelphia, Baltimore, Washington, and the cities on the southern coast.

All the cities of Maine harvest their own local supply, but the principal cutting is done on the Kennebec and Cathance rivers, the Sheepscot river, and the Penobscot. Accessible to shipping, these streams export their ice. The first house on the Kennebec was built at Richmond in 1826, at a time when the operations of Mr. Tudor in Boston were attracting general attention. It was abandoned to natural decay about ten years afterward. The business made little progress in Maine until 1870, when a warm winter caused almost an entire failure of the crop on the Hudson and the Schuylkill. The ice dealers of those rivers became alarmed. They were obliged to buy ice in Maine for from \$7 to \$8 a ton, and in Massachusetts for \$10. They had had similar experiences before, and the failure of their crop in 1870 convinced the large companies that they would do well to locate at least a part of their plant in some northern locality, which could be depended on for a sure annual supply. There were then only 8 companies on the Kennebec and few anywhere else in Maine. But after 1870 there was a rapid increase in their number, and the ice business of the Kennebec and central Maine grew steadily year by year. One after another the following companies built houses on the Kennebec and its tributaries and on the neighboring Sheepscot river: the Knickerbocker Ice Company of Philadelphia, the pioneer; the Hancock Ice Company of Philadelphia; the Knickerbocker and the Consumers' ice companies, of New York; the Great Falls and the Independent ice companies, of Washington, D. C.; and W. H. Oler & Co., of Baltimore. A large number of new houses were also built by the Maine people themselves.

Maine ice was much admired in the markets to which it was sent, those markets being the coast cities from New York to New Orleans. It was forwarded in coasting vessels, of which a large fleet was annually required for the purpose. In 1878, the experiment was made of shipping to a distant market by railroad. Four freight trains of 20 cars each were loaded with ice at \$1 50 per ton and dispatched to Saint Louis, where they delivered in good condition 672 tons out of a total shipment of 1,275. The freight cost \$5 80 per gross ton, and the ice sold for \$10 50 per net ton. Owing to the waste of 50 per cent., the venture netted a large loss, and was not repeated.

The first great year on the Kennebec was that of 1879–'80. The harvest had been proceeding quietly through January and February, when word came from New York that the Hudson ice crop had failed, and that wholesale prices had risen in New York to \$4 and \$5 a ton. Ice was from 15 to 20 inches thick on the Kennebec, free from snow ice, smooth enough to cut without planing, firm, hard, and brilliant. It could be cut for 20 cents a ton; loaded on vessels for 50 cents; freighted to New York for 50 cents; and landed there at a cost of about \$1 50 per ton. The advices received were so favorable that all the ice-men of the Kennebec were thrown into a state of

great excitement. The companies all prepared to cut immediately as much as they could handle; and a number of new concerns promptly invested a good deal of money in tools and went into the business. Every idle workman along the river was employed and put to work. Shipyards and saw-mills were applied to for sawdust to pack the ice; the demand was so large and the supply so inadequate that the sites of old saw-mills were hunted up in order to dig out sawdust several years old. The price rose to $3 per cord. Marsh hay, also used for packing, rose from $5 per ton to $10. Spruce and hemlock lumber for dunnage increased in price also. The river was a scene of remarkable animation. The dealers foresaw fortunes, and they pushed operations with the utmost energy. The portions of the river where cutting was done were covered with an army of 4,000 men and 350 horses, and work was prosecuted day and night. At Boothbay, a few miles from the Kennebec, and at other places, the houses were filled to the roof-plates, and thousands of tons were then stacked in the open air upon the ground for transfer to schooners for immediate dispatch to market. Similar scenes were enacted on the Penobscot, near Bangor and Brewer. When the harvest had ended, a total of about 1,300,000 tons of ice had been gathered in Maine. Of this, 950,000 had been cut on the Kennebec; 150,000 on the Penobscot; about 110,000 on the Sheepscot; and the rest at scattering points all along the coast. On the Penobscot, this was the first year in which ice had been cut in any large quantity. For fifteen years there had been no such business excitement in Maine.

In marketing the large product of 1880 there was good success. To cut and house the ice cost from 14 to 22 cents a ton, according to locality, the thickness of the ice, and the amount of machinery used. To transfer it in the spring and summer to the holds of the schooners cost an average of 42 cents per ton, including dunnage. Freights were from 50 cents to $1 25 to New York or to Philadelphia; from $1 to $1 75 to Baltimore, Savannah, and the West Indies; and a dollar more to New Orleans. There were a few cases early in the year when the supply of shipping was small, in which freights were $3 and $4 per ton. Large vessels were ordered by cable from Europe to load at $3 per ton freight. But this state of affairs wrought its own cure by bringing to Maine an abundant offering of tonnage, so that during the most of the year the freight averaged not over $1 per ton to the middle Atlantic ports. The whole harvest of 1879-'80 not required for home consumption was sold at not less than from $1 to $1 75 per ton. A portion of it was disposed of, late in the summer, at higher prices. A few concerns sold out at $3 per ton; and several shipments were made at $5 and $6 per ton, delivered on board. It is safely estimated that the crop brought to Maine about $1,500,000, of which sum $600,000 was expended among the workmen who cut, stored, and transferred the ice to the shipping, working for from $1 to $1 25 per day. A further sum of more than $1,000,000 was earned by the vessels carrying the ice to market. In all, close upon 2,000 cargoes were shipped, 1,735 from the Kennebec and locality, and 250 from the Penobscot and eastern coast. The shipments from the Kennebec region during the year of 1880 were, per statement prepared by John H. Raymond, deputy collector at Bath, as follows:

To what port.	Number of vessels.	Tons of ice.	To what port.	Number of vessels.	Tons of ice.
New York	581	257,518	Bridgeport	1	466
Philadelphia	658	339,444	Norfolk	2	767
Baltimore	177	111,929	Wilmington, Delaware	2	770
Washington	97	63,186	Port Jefferson	2	555
Newark	30	13,762	New Bedford	1	420
Richmond, Virginia	32	14,218	Galveston	2	917
New Orleans	14	18,870	Jacksonville	6	2,710
New Haven, Connecticut	26	12,683	Portsmouth, Virginia	1	395
Wilmington, North Carolina	13	6,429	Camden, New Jersey	1	390
Charleston, South Carolina	10	5,284	Atlantic City	3	1,198
Savannah	17	10,030	Flushing	1	399
Providence	10	5,078	Fredericksburg, Virginia	1	400
Georgetown, District of Columbia	10	5,283	Petersburg, Virginia	4	1,495
Greenport, New York	3	1,335	Fall River	2	1,086
Staten Island, New York	5	2,726	Narraganset Pier	1	440
Annapolis	1	460	Gloucester	1	467
New Castle, Delaware	3	1,613	Fernandina	1	450
Newport	7	2,872	Unknown	5	2,616
Brunswick, Georgia	1	422			
Mobile	3	1,281	Total	1,735	890,364

The profits of the year gave a great stimulus both to the ice business of Maine and the ship-building industry. A number of new houses were built and many vessels were constructed to share in the freighting. The latter were center-board schooners, shoal vessels of light draught and large capacity, adapted for running up the rivers, commanding a somewhat higher rate of freight on that account. So much new capital came into the business, especially on the Kennebec, that there are now on that river alone 36 firms in the business, employing $1,000,000 of capital, owning 53 houses of a total capacity of 1,050,000 tons. On the short stretch of river from Bath to Hallowell there is now more capital concentrated in the cutting and storage of ice than in any other locality of equal extent in the world.

It is to be remarked that shipments from the Kennebec begin, in different years, at dates varying from March 15 to April 15.

On the Penobscot scarce a thousand tons of ice had been cut for shipment before 1879–'80. The stretch of river from Bangor to Brewer froze over annually to the depth of from 15 to 25 inches, but no facilities were created for handling anything more than a local supply until the furore of the year in question. The Bangor men then resolved to enter into the industry. They cut and housed, or stacked in piles along the riverside for 4 miles, about 115,000 tons of ice, which they afterwards sold at paying prices. A good part of the crop was disposed of for $3 a ton. There are now 26 firms in the ice business on the Penobscot, with houses having a capacity of close upon 210,000 tons, located at Bangor, Orrington, Hampden, Brewer, Rockport, Belfast, Saint George, and Rockland. The Penobscot and the Arctic Ice Companies at Hampden and Orrington have been the only ones on the river having steam engines and endless chains to hoist with.

Statistics as to the total cut in Maine during past years are imperfect. The capacity of the 109 houses at present in existence is 1,560,000 tons. There are 53 houses and 1,050,000 tons of capacity located on the Kennebec; 26 houses and 210,000 tons of capacity on the Penobscot; 12 houses with 39,000 tons of capacity on the Cathance river; and on the rest on the coast principally, at Booth Bay, Wiscasset, Damariscotta, and Portland, 28 houses having 281,000 tons of capacity. The actual harvest is believed never to have exceeded about 1,400,000 tons, of which from 900,000 to 1,000,000 tons were on the Kennebec. The harvest fluctuates with the state of the weather on the Hudson and Schuylkill. A good year on these latter rivers results in a smaller production in Maine and *vice versa*.

The companies report the waste of ice while in store in the houses as about 20 per cent. The waste during transportation by vessel to Atlantic and gulf coast markets is also about 20 per cent. The usual sizes of blocks stored for shipment are 22 by 44 inches, and 44 by 44.

MASSACHUSETTS.

The ice business of Massachusetts is concentrated chiefly in the city of Boston. The cities of Worcester and Fitchburg have companies which cut 80,000 tons a year in Worcester county, a part of it for shipment; and scattered throughout the state are many communities which harvest a local supply annually from their ponds and rivers. But Boston is the principal consumer and exporter of the state. There is usually an ample supply of ice on the ponds in the vicinity of Boston. Nevertheless the harvest is subject to great vicissitudes. The weather of the winter months is variable, and it often happens that not over one-half or one-third of a crop can be gathered, and that only too frequently of very poor quality. One of the most productive years ever known was 1855, when a second crop was harvested, a part of it 21 inches thick. Another good year was 1870; the winter was mild on the Hudson and further south, and ice was scarce; but the Boston companies were able to fill their houses with an excellent product; the wholesale price rose from $2 a ton to $10, and the crop was marketed with great profit. But there were other years when the crop was almost a complete failure about Boston. One of them was 1879–'80. As late as February ice had not formed thicker than from 6 to 9 inches, and not much even as thick as that. The dealers were forced to cut ice in New Hampshire and in Maine, and a portion of their supply was purchased from the Maine companies. The number of firms in the business in Boston is 14, of whom 5, with a capital of $510,000, cut principally for the export trade; 8, with a capital of $400,000, cut for local consumption; and one, with a capital of $6,000, cuts for use in its own brewery. The Tudor Company, one of the five exporting firms, is now withdrawing from its foreign trade and building up a local business. In good years the Boston companies harvest, according to census returns, as follows:

Name of company.	Sources of supply.	Ice secured.
		Tons.
Boston Ice Company	Ponds in Wakefield, Wellesley, Woburn, Lynnfield, and North Chelmsford, Massachusetts	180,000
Tudor Ice Company	Fresh pond in Cambridge, Masssachusetts	110,000
T. S. Hittinger	Fresh pond in Cambridge, and Forge pond in Westford, Massachusetts	100,000
Addison, Gage & Co	Wenham lake and a pond in Arlington, Massachusetts	70,000
Jamaica Pond Ice Company	Jamaica, Hammond's, and Curtis's ponds	55,000
Drivers' Union Ice Company	Essex, Massachusetts, and Milton, New Hampshire	22,000
Wenham Lake Ice Company	Wenham lake, and in Beverly, Massachusetts	25,000
South Boston Ice Company	South Weymouth, Massachusetts	20,000
Charles Russell	Wellesley, Massachusetts	25,000
Locke & Downing	Chandler's pond in Brighton, and Strong's pond in Newton, Massachusetts	35,000
Morrell & Buckner	Concord, Massachusetts	10,000
Winkley & Maddox	Essex, Massachusetts, and Newton, New Hampshire	6,000
G. F. Burkhardt Union Ice Company	Wilmington, Massachusetts	11,000
Total		669,000

About 80,000 tons are harvested in the towns around Boston by local companies, making the annual harvest in good years about 750,000 tons. To ascertain the quantity actually consumed, a deduction of 20 per cent. must be made for meltage in the ice-houses, and a further deduction of from 20 to 33⅓ per cent. for waste in handling during distribution. A safe estimate would put it at from 375,000 to 400,000 tons a year, and 175,000 tons of this amount would be the exportation to foreign and domestic ports. A total cut of close upon 900,000 tons is claimed for Boston and vicinity, but the returns of the ice companies to special agent R. T. Swan do not indicate an aggregate larger than above set forth.

The ice-houses of the Boston companies are usually of wood, costing 75 cents per ton of capacity. A few are of brick, costing $2 per ton to erect. The usual size of block for storage is 44 inches square. For export the blocks are sold without dividing them, but for the local trade they are split up into 22 inches square. The ice is sent into town in railway-cars built for the especial purpose and carrying 5 or 6 tons each. Most of the retail companies load their distributing wagons at night for the next day's business, a practice which is said to result in a good deal of waste in spite of its convenience, for the wagons then stand all night in sheds. Wagons without springs were formerly used, but a change is now taking place in favor of springs. Drivers deliver on their routes from two to seven loads of about 3 tons each per day.

The prices of ice in Boston vary, as elsewhere, with the quantity cut the previous winter and the warmth of the summer. The wholesale price averages $1.50 per ton, but in 1880 it was about $6. To families and small consumers a fair average price is $3 per ton in winter and $8 per ton in summer.

NEW YORK.

The ice business took its rise in New York state shortly after its successful initiation in Boston. At the mouth of the Hudson river were the cities of New York and Brooklyn and the communities which are now united into Jersey City. Scattered along the river were what are now Newburgh, Poughkeepsie, Peekskill, Rondout, Hudson, Athens, Albany, Troy, and various other intermediate towns of smaller size. As these communities grew into importance the ice business kept pace with their demands, and the Hudson river has now been for forty years the principal center of the industry in the United States. New York city and suburbs require 1,500,000 tons of ice yearly, and they sell some ice to shipping and for export, while the cities along the river require about 500,000 for their own local consumption. There is no exact statistical account of the total quantity of ice annually cut on the river and adjacent lakes. The capacity of the storage-houses is known, however, and a rough calculation of the crop is made every spring for the benefit of the trade. From these data and the known consumption of the cities along the river an approximate and pretty safe estimate of the average crop can be made. It would appear that the river region now supplies from 2,000,000 to 2,750,000 tons of ice every fairly good winter. Even this quantity, however, is not sufficient for the market. A crop of 2,000,000 tons dwindles to 1,000,000 tons before it reaches the consumers by meltage in the houses, and by waste in forwarding to market and distribution through the cities. A part of the deficiency is now made up by the manufacture of ice in the breweries and by artificial refrigeration. The balance is supplied by the state of Maine and the lake Champlain region.

Great uncertainties attend the industry on the Hudson. The weather is variable, and in not more than two out of three years is the crop a fair one. The ice seldom forms to a greater thicknes than 12 inches. The companies prepare for the harvest the moment they have 6 inches, and if the season is late they fill their houses with from 6- to 9-inch ice. A thaw with a rain storm often ruins the crop just as the companies are on the point of beginning operations. Should the crop be a small one, and the price of ice high the following summer, the large profits result in the immediate erection of a number of new houses, and every effort is made the succeeding winter to gather as much ice as possible. The result is that prices are apt to range so low for a year thereafter that there is no profit in the business. In such cases owners often carry their store of ice over until the following season as less likely to be productive of loss. Wholesale rates have been known to be $1.50 and $2 in one year, and from $10 to $12 a part of the next.

For the New York market ice-cutting is done on Rockland, Kensico, Tuckahoe, Croton, Mahopac, Greenwood, Highland, and Meahagh lakes, all in the lower counties of the state, and on the Hudson river from Poughkeepsie to Troy. The ice-houses are more numerous as Albany is approached. The principal centers of operations are Rondout, Glasco, West Camp, Athens, New Baltimore, Coxsackie, Castleton, Albany, and Troy. In all there are 135 ice-houses between New York and Albany and about 25 more on the upper Hudson and lake Champlain, which are tributary to New York. There are also many small houses on the Hudson, of 3,000 to 5,000 tons, owned by local dealers. A very nearly perfect list of the houses between New York and Albany, a number of small local establishments being omitted, has been prepared by a well-informed man in New York for the *Ice Trade Journal*. It is as follows:

Locality.	Name of company or firm.	Dimensions.	Capacity.
		Feet.	*Tons.*
Lake Mahopac	Smith, Lymington & Co		25,000
Croton lake	National Ice Company		50,000
Greenwood lake	Cooper, Hewitt & Co	250 by 200	45,000
Rockland lake	Knickerbocker Ice Company	362 by 158	45,000
Do	do	230 by 190	35,000
Lake Meahagh	do		40,000
Highland lake	A. C. Cheney & Co	230 by 200	40,000
Marlborough	Knickerbocker Ice Company		25,000
Poughkeepsie	Carpenter & Co		3,000
Do	Myers & Co		5,000
West Park	J. Mulford	177 by 150	20,000
Do	Mutual Benefit Company	300 by 225	40,000
Staatsburg	do	100 by 60 100 by 100	15,000
Do	Knickerbocker Ice Company	342 by 117	25,000
Esopus	do	250 by 140 300 by 204 170 by 100	75,000
Do	Commonwealth Ice Company		20,000
Port Ewen	Knickerbocker Ice Company		40,000
Rondout creek	do	250 by 105	17,000
Do	do	200 by 60	8,000
Do	Brewers' Ice Company	120 by 120 158 by 150	51,000
Do	J. Hoffman		10,000
Kingston point	Kingston City Ice Company	75 by 40	1,800
Rhinebeck	Knickerbocker Ice Company		18,000
Whisky point	do		40,000
Do	do		17,000
Do	Newark City Ice Company		16,000
Flatbush	do	200 by 200	28,000
Do	Knickerbocker Ice Company	312 by 206	48,000
Do	do	121 by 100	7,000
Do	New Jersey Ice Company	200 by 111	15,000
Barrytown	Livingston & Co	206 by 154	16,000
Do	Mutual Benefit Ice Company	257 by 150	30,000
Turkey point	Knickerbocker Ice Company	300 by 126	25,000
Glasco	do	200 by 100	15,000
Do	G. C. Preston		8,000
Do	Oakes & Thompson	201 by 153	25,000
Do	Glasco Ice Company		30,000
Evesport	Knickerbocker Ice Company	200 by 116	16,000
Smith's landing	Sturges & Martin		17,000
West Camp	Knickerbocker Ice Company	200 by 150	21,000
Do	National Ice Company	300 by 200	40,000
Do	New Jersey Ice Company	250 by 200	35,000
Do	Consumers' Ice Company	400 by 200	61,000
Do	do		20,000
Germantown	Rockefeller & Co		11,000
New Paltz	Knickerbocker Ice Company	250 by 83	12,000
Catskill	do	280 by 172 106 by 82 120 by 120	43,000
Do	H. Van Steenburgh	186 by 112	11,000
Do	do		6,000
Rodger's island	Knickerbocker Ice Company	200 by 200	26,000
Hamburg	New York City Ice Company	340 by 200	50,000
Do	do		25,000
Do	Knickerbocker Ice Company	198 by 132	19,000
Athens	Arrow Ice Company	220 by 207	33,000
Do	Howland & Son	157 by 116	11,000
Do	Theodore Avery	102 by 84	8,000
Do	Hudson Ice Company		30,000
Do	Knickerbocker Ice Company	357 by 202 394 by 90	85,000
Four-Mile point	Brewers' Ice Company		55,000
Do	H. Rogers		12,000
Do	James Saunders		8,000
Pine grove	F. A. Andrews		11,000
Do	Knickerbocker Ice Company		40,000
Stockport	Stockport Ice Company		35,000
Coxsackie	Knickerbocker Ice Company	300 by 160 300 by 200	85,000
Do	do		31,000
Do	do		10,000

Locality.	Name of company or firm.	Dimensions.	Capacity.
		Feet.	*Tons.*
Coxsackie	Hudson Ice Company		17,000
Do	Rea Bros		6,500
Do	National Ice Company		5,000 37,000
Do	Green County Ice Company		12,000
Do	David Terry		1,500
Coxsackie island	Ridgewood Ice Company		35,000 20,000
Stuyvesant	New Jersey Ice Company	250 by 110	20,000
Do	Scott & Co	240 by 100	15,000
Do	Yonkers City Ice Company		40,000
New Baltimore	Shaddon & Co		10,000
Do	A. J. Vanderpoel	105 by 105	8,000
Do	Horton & Co		20,000
Do	Knickerbocker Ice Company		25,000
Do	Vanderpoel, Van Orden & Co		10,000
Do	Smith & McCabe	154 by 102	11,000
Do	G. R. Miller		12,000
Schodack channel	Scott & Co		15,000
Do	McCabe Bros		10,000
Do	Gardiner & Schermerhorn		20,000
Do	Knickerbocker Ice Company		50,000
Do	Downer & Herrick		6,000
Pook hook	Knickerbocker Ice Company		20,000
Ziegler's island	do		12,000
Barren island	do		35,000
Coyemans	J. A. Briggs		10,000
Do	Knickerbocker Ice Company	250 by 196	33,000
Do	Bean & Parker		8,000
Do	James A. Warren	163 by 154	18,000
Castleton	C. Warren & Son		15,000
Do	W. H. Phibbs		10,000
Do	H. Buckley		4,000
Do	F. E. Bean		8,000
Do	Miller & Ostrander	93 by 88	4,500
Do	Yonkers City Ice Company		30,000
Do	Ridgewood Ice Company		55,000 10,000
Do	Commonwealth Ice Company	167 by 100	11,000
Do	do		10,000
Do	Baker & Son		8,000
Campbell's island	R. English & Co	209 by 190	30,000
Cedar hill	do		35,000
Do	Allen & Co		5,000
Staats'	Freeman & Herrick		10,000
Van Wie's point	A. Dettinger	225 by 150 200 by 150	65,000
Jolly island	Houghtaling & Co	229 by 113	39,000
Dow's point	J. Patterson	110 by 76	6,000
Do	Gascoigne Bros	100 by 60	4,500
Greenbush	S. Vrooman & Co		15,000
Do	H. D. Moulds		25,000
Do	W. Smith		15,000
Do	C. Warren & Son	90 by 60	4,000
Albany	H. Houghtaling	144 by 144	13,000
Do	Knickerbocker Ice Company		20,000 8,000
Do	Rose & Wilbur	226 by 90 95 by 95	19,000
Do	Rouan & Sampson		25,000
Total capacity			2,866,800

To reach the full productive capacity of the Hudson river companies, half a million tons should be added to the figures above. That quantity of ice is sometimes cut and stacked on the banks of the river, and sold and shipped before the warm weather comes on.

These houses are almost universally supplied with endless-chain elevators driven by from 25 to 35 horse-power engines. The companies own large outfits of tools, and they employ every modern device for saving labor and expediting the harvest. Speed is of the utmost importance. When there is good ice the houses are filled severally in from ten to twenty days after cutting begins. In good years the industry employs close upon 20,000 men and 1,000 horses. The men are recruited largely from the brick-yards of the river, which are idle in the winter time.

The wages paid vary from $1 to $1.50 per day. The cost of cutting and housing is from 25 to 50 cents per ton. A harvest of 2,500,000 tons is therefore the means of disbursing about $900,000 in ready cash to the inhabitants of the river towns.

There have been many open winters on the Hudson. A notable one was that of 1869–'70, when the crop was so small that ice sold for from $16 to $25, a little at $30, per ton the following summer. The dealers also had small success, in 1879–'80. The river did not close until the middle of January. A month later there had been only a scanty harvest of 4- to 8-inch ice at scattered points. The dealers then realized the danger of the winter passing without a harvest, and there was a rush with men, horses, tools, and building material to the upper Hudson, above Albany, and to lake Champlain. The Knickerbocker and the Consumers ice companies made arrangements for a part of their supply in Maine. In that winter there were not over 600,000 tons of old and new ice on the river and neighboring lakes; and much of the new crop was soft and spongy. Agents from Canada visited New York to sell ice, and arrangements were made for purchasing a few cargoes in Norway. Maine was the chief reliance for good ice that summer. The only thing that prevented a repetition of the famine prices of 1870 was the fact that about 400,000 tons of old ice had been carried in the Hudson river houses from 1878–'79. Prices rose sufficiently high, however, as soon as spring had arrived and dealers realized that the supply was scant. In January the wholesale price had been $1.50 to $2 per ton. The rates then rose as follows: in February to $3 per ton; March, $5; April and May, $7; June and July, to $8 and $10; August, $10 and $12; September, $8 and $9; October, $8; and November, $6 and $7. These were the rates for large consumers, brewers, packers, butter dealers, hotels, and saloons. At retail, to families, the rates in the hot months rose to 60 and 75 cents per 100 pounds, and finally for a short time to $1, equal to $20 per ton. The houses on the Hudson river were virtually emptied during the summer. From the Kennebec, in Maine, 257,000 were imported, and many cargoes from other parts of the State; from Canada, by rail and canal, 15,000 tons; and from Norway, 8 cargoes amounting to 18,000 tons. The latter ice was good, pure, and hard, in cakes of 24 inches; it sold at the wharf at $7.50 wholesale; very little money was made on its importation.

The winter of 1880–'81 was a severe one. A large crop was harvested, and prices dropped back again to almost unremunerative rates. The wholesale price ranged from $1.50 to $2 through the summer; the retail price to small consumers from $4 to $8; the dealers and drivers paid $2 per ton, and considering that the waste in delivery is from 25 to 33 per cent. and the expense of distribution about $1.50 per ton, the retail price during most of the summer was too low for profit. Such are the vicissitudes of the ice business. The only advantage to the companies of the low prices was that it increased the consumption of ice permanently; and in 1882 the market took a larger supply than ever at fairly-paying rates. In years of excessive production new uses for ice are discovered, which give rise to new and important sources of demand.

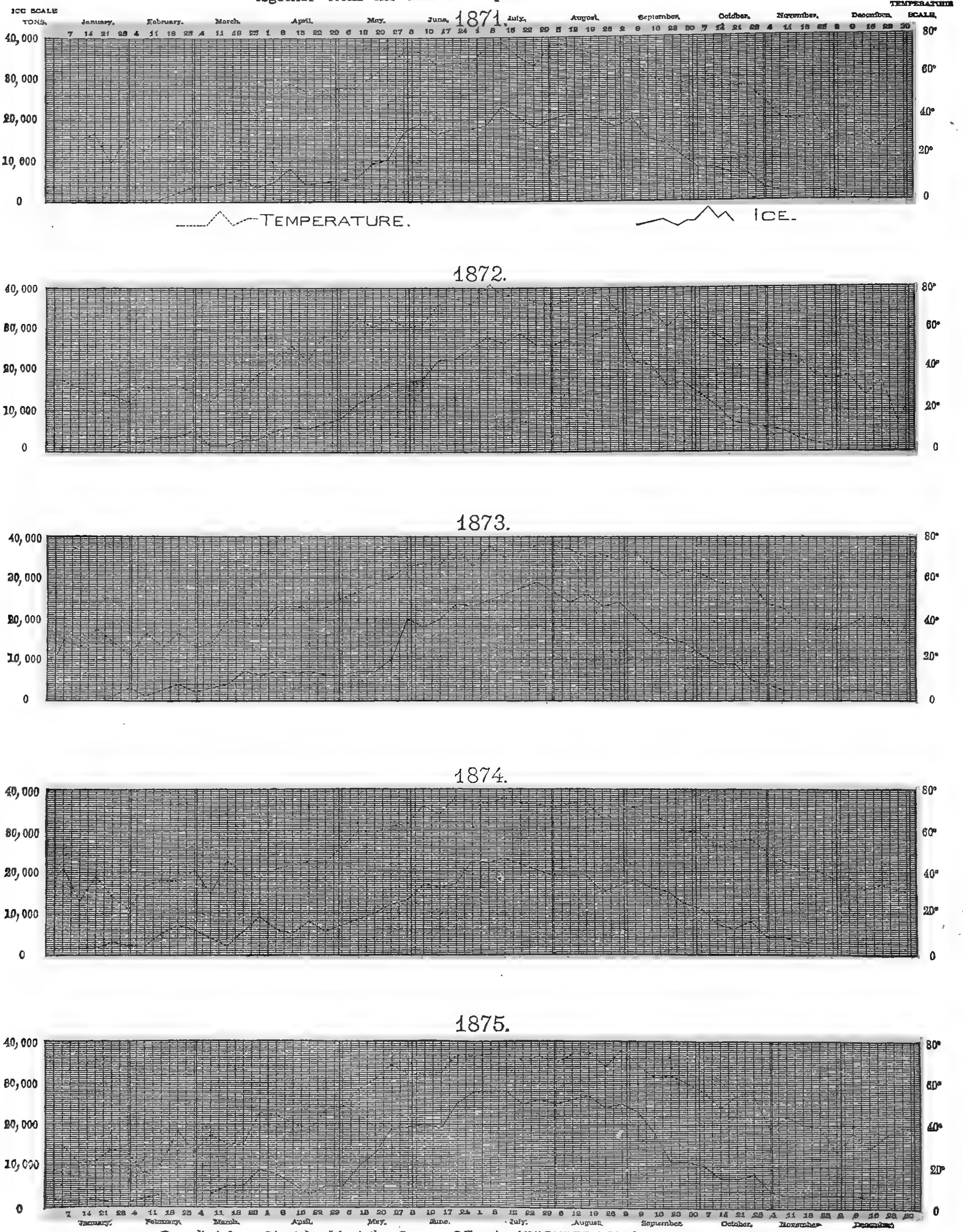
The ice-houses on the Hudson are located chiefly on the western bank of the river. They are all of wood, with double walls from 20 to 36 inches thick, the inner space packed with sawdust. A few are not boarded up on the outside of the frame, but all the new houses have the double walls. The lofts are high and spacious. The houses set almost invariably broadside to the river. In connection with the largest of them there are usually outbuildings—barns, workshops, tool-houses, and boarding-houses. In Ulster county the Knickerbocker Ice Company has a large farm for the raising of grain and hay. Much land elsewhere along the river is cultivated by ice companies for a similar purpose. At Rockland lake a railroad and inclined plane run over the summit of the mountain to the Hudson river for the transfer of ice to barges. When the harvest is over each winter the army of cutters is disbanded, and a smaller force is employed to cover the ice with hay, close the rooms, house the tools, make necessary repairs, and clean up the débris of the winter's work. In the summer a fresh force is employed in opening the houses, taking out the ice, loading it on cars and boats, and, in case of the boats, navigating them to New York, Brooklyn, Jersey City, and Newark.

The size of block popular on the Hudson is 32 by 22 inches. It is a convenient size to handle. If the blocks were thicker than they generally are a smaller size would be preferred.

The distribution of ice in New York city is carried on partly by the regular companies and partly by independent dealers and drivers of ice-wagons. There are thirteen depots in the city (mostly on the Hudson river front) at which the ice is unloaded and transferred to the wagons; and it is then distributed by wagons having regular routes. In the statistical returns no account is taken of the number of independent dealers, so that there may not be a duplication of returns of consumption. It is estimated that 700 wagons and teams of horses are employed in distribution in New York city.

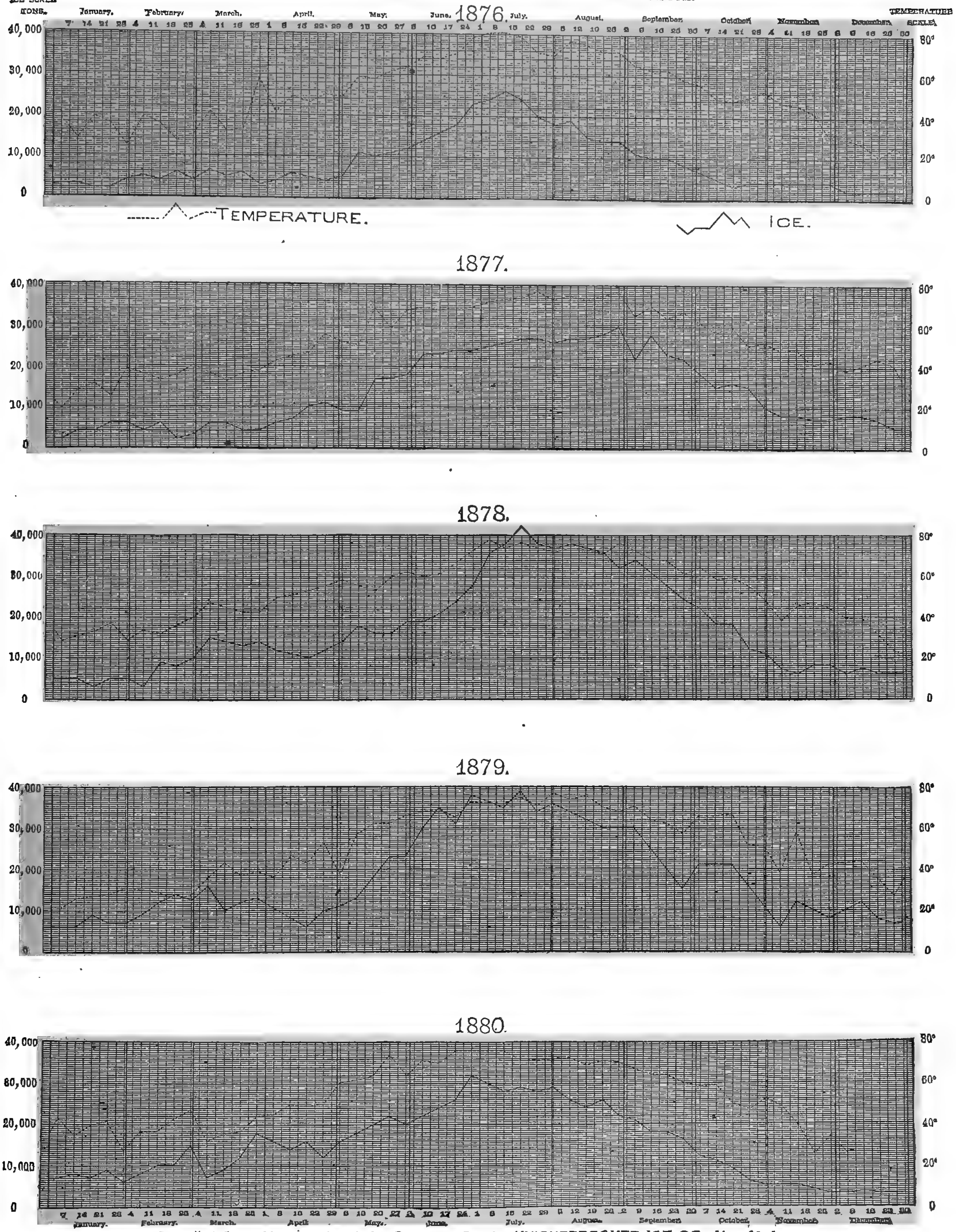
At the request of Mr. Charles E. Hill, chief special agent of the census for New York city, a chart was prepared by Mr. Ballentine, of the Knickerbocker Ice Company, for this report, which is presented herewith. It shows, by profile, the weekly consumption of the ice in New York and Brooklyn, in tons, and the weekly average of the thermometer readings for the corresponding weeks, extending over a period of ten years, from 1871 to 1880. The chart is the result of much patient care and labor, and is a valuable indication of the general fluctuations of the consumption of ice in the two cities.

CHART showing weekly Sales of Ice in Tons for **NEW YORK and BROOKLYN,**
from 1871 to 1875 inclusive.
together with the Mean Temperature for each Week.



Compiled from Chart furnished the Census Office by KNICKERBOCKER ICE CO., New York.

CHART showing weekly Sales of Ice in Tons for NEW YORK and BROOKLYN, from 1876 to 1880 inclusive, together with the Mean Temperature for each Week.



Compiled from Chart furnished the Census Office by KNICKERBOCKER ICE CO., New York.

In Brooklyn the ice supply arrives almost entirely by boat from the Hudson river. Perhaps 10,000 tons are cut in good seasons at ponds on Long Island for the use of brewers and packers, but the main dependence of the city is the Hudson river. The Knickerbocker and the Ridgewood companies supply nearly the whole of the quantity consumed in the city. About one-third of the crop harvested by the Knickerbocker Company is required by its Brooklyn trade. There are a number of small concerns and independent drivers in the city, but of these no account is taken in the statistical returns in order to avoid duplication.

PENNSYLVANIA.

Pennsylvania is third in the list of ice-producing States. Streams and ponds abound, from which good pure ice of sufficient thickness can be taken in average years. Statistics of the annual harvest and consumption were gathered, however, only with relation to the city of Philadelphia. With the data at command, it is difficult to estimate the precise extent of the ice production of the state. Philadelphia alone ordinarily consumes close upon 500,000 tons, which means a harvest of about 900,000 tons. The rest of the state probably consumes as much more. All of the many industrious communities of the state have each from 1 to 12 ice firms which harvest for local consumption, some of them occasionally sending ice by rail to Philadelphia and to Pittsburgh; and the known product of a majority of these firms makes the estimate above a safe one.

For the Philadelphia market ice was originally cut wholly on the Schuylkill, above Fairmont dam, and afterwards above the dam, at Manayunk, and finally as far up the stream as Norristown. In winters of ordinary severity an abundance of good ice, 10 to 12 inches thick, forms on the river, and there is good railway communication between the houses and the city. Of late years a part of the ice-cutting has been done on the Delaware, 20 miles above the city, where occasionally the ice is 18 inches thick; on the Lehigh river, Perkiomin creek, and various ponds in the northeastern part of the State. The cheapness of transportation by water from the upper Delaware has been the inducement to the companies to operate in that region. The city now regularly depends for a part of its supply on the state of Maine. The Knickerbocker Ice Company of Philadelphia was the first one in the Middle States to operate in Maine. Its ponds, ice-houses, facilities for loading vessels, and other plant at Booth Bay, are extensive and of the finest description. The cheapness of ice in Maine, its great thickness and density, and the low cost of its transportation to market by coasting schooners, have led to the Knickerbocker company's harvesting at Booth Bay about one-half of the 400,000 tons it requires every year. The other dealers also obtain large quantities of ice from Maine, their trade being with the Kennebec region; and the certainty with which an adequate supply can be secured from that part of the country makes the practice a growing one. For the last three years the streams in the vicinity of Philadelphia have yielded only a small quantity of not very good ice. Either the winters have been open ones or the ice, when formed, has been damaged by bad weather. At present about one-half of the whole supply of the city is drawn from the state of Maine.

The Knickerbocker company ranks, with its namesake in New York, as one of the largest ice concerns in the United States. It employs in distribution $300,000 of capital, 800 men, and a large number of wagons, and pays out in the city about $250,000 annually in wages and incidental expenses. Its annual sales approximate 200,000 tons, of which 30,000 are for export. The company was formed in 1869 by the consolidation of the old Knickerbocker company with seven others. In 1873 Mr. Thomas E. Cayhill, its president, proposed the establishment of a depot for the manufacture and sale of the tools, elevators, and machinery used in the trade. A shop which they were employing for the construction of wagons was enlarged and fitted up, and the factory has since been doing an extensive business with all parts of the country. One of the original ideas of the company has been the application of the endless-chain elevator to the handling of ice on the pier at which the vessels from Maine unload. A brick ice-house has been built on the pier, with a platform running out along the water's edge the whole length of the pier. The ice from the ship is unloaded upon this platform, and is either transferred to the wagons ranged along the other side of it, or is carried by the endless-chain elevator to the store-house. The part of the platform adjacent to the house can be raised or lowered by windlass-power to suit the height of the ice within. By reversing the machinery the endless chain serves the purpose of taking a supply from the house and distributing it to the wagons backed up against the platform. An illustration of this arrangement on another page of this report, will more fully explain its convenience and ingenuity.

The average wholesale price of ice in Philadelphia in 1880 was $3 75 per ton, but $5 75 and $6 were the rates a portion of the summer. The price to small consumers per 100 pounds was 20 cents down to the 1st of May, and 40 cents thereafter. In 1879 the wholesale price was about $2 50 per ton. In 1870, a year of short supply, it was as high as $15.

Pittsburgh, Meadville, Oil City, and other towns in western Pennsylvania harvest some ice in their respective localities, but they depend on Chautauqua lake in New York for a large part of their supply.

OHIO.

In winters of ordinary severity good ice forms in every part of the State of Ohio. It is naturally most abundant in the northern counties; thinner but in sufficient supply in the southern. The demand for ice is large in the state, owing to the density of the population and the extent to which the various towns carry on the brewing of beer and packing of meats. Every community has its ice-houses, and local harvests are always gathered when the weather permits. When the crop fails in the inland counties, as it does in part in about every third winter, extraordinary efforts are made to secure a supply of ice from any point at which it can be obtained, either within or beyond the State. Indiana is a favorite resort of the Ohio ice men. The usual practice is to buy in Cleveland, Sandusky, and Toledo, on the shores of the lake. It is sometimes necessary to go to the lakes in Michigan and Wisconsin, and in the early spring of 1880 the Cincinnati men even bought largely from Lachine and Montreal, Canada.

The most important center of the trade is Cincinnati, on account of the large number of its brewing and packing establishments. The business is controlled by three large companies, who cut their ice on natural and artificial ponds located from 5 to 100 miles from the city in Ohio and Indiana, from the Little Miami river, Mill creek, and the Miami canal. There are 60 houses belonging to the companies and to various private owners in adjoining towns. The storage capacity is 450,000 tons. This is more than Cincinnati actually requires in any one season, but bitter experience has taught the dealers to house enough ice in a sharp winter to last two years if necessary. There have been several ice famines during the last twenty years, during which $40 a ton has been paid by those who did not have contracts with the regular and responsible dealers. A large amount of ice is now carried over every year to provide against emergencies, and so that the dealers may reap the benefit of any scarcity the following winter. Two-thirds of the ice cut is brought into town by the Miami and Erie canal, the balance by railroads. Besides the regular companies there are a number of farmers and small operators in the ice business. They cut in the townships around the city and deliver to sundry private individuals for their own consumption. Of late years the brewers and packers have practiced employing these small dealers and others to cut for them in the winter time from 500 to 6,000 tons of ice to store in their own houses. They have adopted this plan to save the profits of speculators. Their factories are largely adjacent to Mill creek and the Miami canal, and the ice is generally cut there. Some of the largest brewers have also introduced ice-machines into their factories of late. As industries, the brewing and packing of Cincinnati are now nearly independent of the regular dealers, and this has considerably affected the trade of those concerns. In 1880 the brewers and packers cut 46,000 out of the 87,000 tons of natural ice consumed by them.

The actual consumption of Cincinnati ranges from 200,000 to 225,000 tons yearly. To meet the demand there is a harvest amounting (with the old ice carried over) to about 350,000 tons. The actual harvest varies from 150,000 to 400,000 tons. The vast bulk of all the cutting is done by the regular companies, who own 240,000 tons out of the total storage capacity above referred to. The winter generally allows field work to begin the latter part of December or in January. It is dangerous to wait until February before storing ice, but sometimes the companies must thus wait. The ice at Cincinnati is from 6 to 12 inches thick. In years of scarcity the dealers have to act with great energy. They prospect in the north, along lake Erie, and up into Michigan and Wisconsin, until they find good ice which can be bought to advantage, and they purchase and forward as much as possible of their supply while the cool season lasts. Northern firms often establish agencies in Cincinnati in such years, and sell direct from the cars to consumers and dealers at lower prices than the regular companies. These agencies are always of a temporary character. They are closed on the approach of the following winter. The wastage of ice between the source of supply and point of distribution is reported in Cincinnati about 33 per cent. Brewers and packers who get in their own ice report no waste. They haul and store their ice as soon as it is cut, and do not remove it from the store-house.

There is very little danger of an ice famine or of fancy prices in the future. The annual product is now too large. Prices vary in Cincinnati with the quantity in store and the quality of the stock. The cost of cutting and storing at the river side, or at the pond, appears to be from 50 cents to $1 per ton. Before it can be sold for distribution a further charge must be made for freighting profits and interest. This charge necessarily varies with different firms. Some houses are located so advantageously that the cost of transportation is nominal, whereas those at a distance from the city are at heavy expense when forwarding their store to market. The brewers report that it costs them from 50 cents to $1 50 per ton to house a supply of ice from their locality. When they buy of the regular dealers in the summer months they must pay from $3 to $6 per ton, according to the quality of the ice and the season. For the general trade the wholesale prices by canal-boat load of 60 tons should be from $4 to $6 per ton; in abundant years it falls to $2 and $2 50, whereas in years of short local crop it goes to $10. The rate for families and small consumers varies every year. In 1880 hotels, markets, and saloons paid from $14 to $16 per ton, buying by the 100 pounds, and families paid $20. The fair average price to families in abundant years is $6 or $7 per ton in winter, and $10 or $12 in summer. Cincinnati does not have as large a river trade in this commodity as would be fair to expect, in view of her large tonnage of steamboats and barges and the active business her merchants drive with all points in the south. Occasionally a little ice is shipped to points in Georgia, Kentucky, and

Tennessee by rail; but, as a rule, the city does not export, unless the 7,000 to 10,000 tons sold to steamboats for consumption on board and to railways for refrigeration on railway cars be considered as exports. The fact is the city seldom has a ton more than she needs herself, taking the bad seasons with the good.

Chief Special Agent Henry Cole estimates that the capital employed by the Cincinnati companies in harvesting and transporting ice to the localities of distribution is $685,000; that the average number of hands employed is 2,500, and the aggregate amount of wages paid to the same is $49,000. In the city $248,000 of capital and 260 hands are regularly employed in distribution. Returns show a total of 967 people employed in distribution a part of the year.

The part of Ohio in which the ice business is carried on to the best advantage is the section bordering on the shore of Lake Erie. These northern counties are subjected to severe weather in winter, and they are never so destitute of ice that they do not have all they want for local consumption, and an abundance to spare for the interior towns. The business is carried on principally at Cleveland, Sandusky, and Toledo; and if at one of these cities they cannot harvest a full crop, the others are pretty certain to have a surplus. It is rare that there is even a partial failure of the crop along the whole shore. Cleveland is the main consumer. Toledo and Sandusky operate chiefly for the interior trade.

Cleveland consumes the most ice by virtue of her industries. The city has many breweries, packing-houses, and fish-markets, to all of which an abundance of ice is as the breath of life. The family and retail trade of the city does not take more than a quarter of the whole quantity of ice consumed. The waters upon which the companies operate are the Cuyahoga river, Rocky river, a number of ponds in and around the city, and Lake Erie. In good winters ice forms far in excess of the needs of the city, and of a thickness of from 12 to 20 inches, being hard, clean, and pure. The weather is, however, somewhat variable, and safety requires cutting to begin when from 8 to 11 inches are attained. The brewers generally cut for themselves from small artificial ponds, sometimes from the river and the lake. Many of them have introduced refrigerating machines; but natural ice is cheaper than the manufactured, and it pays to allow the machines to rest and to fill the houses from the ponds, when that can be done. They report the cost of so doing at from 25 to 50 cents per ton for cutting and storing. From $1 to to $2 per ton is paid when they have to buy from regular dealers. The total storage capacity of the dealers and manufacturing establishments combined is about 260,000 tons. The average crop stored is 210,000 tons. The average consumption is from 125,000 to 135,000 tons. Brewers report that the waste in hauling and in the house does not exceed 10 or 15 per cent., but the regular dealers encounter a loss of from 25 to 40 per cent. when their houses are near the city, and from 50 to 66 per cent. in all when the houses are at a distance. Inquiries made by M. M. Hobart, chief special agent for Cleveland, indicate the employment of $540,000 and 1,900 men in harvesting and storing. The wages paid to the men is about $60,000 in average years, or about 30 cents per ton. One of the companies, which has a large investment on Rocky river, employs barges of about 150 tons capacity to bring the ice to the city. The blocks from that stream are valued for their purity and thickness. Cleveland is fortunate in her almost complete freedom from the dangers of an ice famine and in the low prices which prevail. The wholesale rate for ice seldom goes to $6 per ton, and it is more likely to be about $2 and $2 50, sometimes $1 00.

Sandusky has a storage capacity equal to 150,000 tons. A large part of it was created in the excitement of the winter of 1879-'80, when the crop failed in so many other parts of the country. Large houses were built in February and March with a capacity of 60,000 tons, and the companies went further and prepared apparatus for stacking considerable quantities of ice for shipment to the interior. The local consumption of Sandusky does not exceed from 16,000 to 20,000 tons, so that when the houses are filled, as they generally are every winter, there is an immense surplus for shipment to interior towns. Sandusky ice is in great demand. It is generally from 14 to 20 inches thick and as clear as plate-glass. Columbus, Springfield, and Cincinnati buy a great deal of their supply at this point. The freighting of from 100,000 to 130,000 tons of ice yearly to these and other towns is a source of great profit to the railroads.

Toledo can store about 160,000 tons. Her dealers operate both in the vicinity and on the lakes and rivers of Michigan. They have an abundance of ice of good quality, generally from 12 to 20 inches thick. The city ships by rail to numerous interior markets.

ILLINOIS.

The ice business of the southern part of the state is tributary to the Saint Louis market, as noticed elsewhere. It remains to speak of the business of Chicago, in the northern part of the state. It is the principal center of consumption in Illinois, and the operations of its numerous companies dwarf the industry in the rest of the state by comparison.

The history of the trade in Chicago dates back to 1847. A house holding 2,000 tons was put up by two men named Frisbie and Burroughs, who filled it with ice taken from the North Branch. In 1848 a house was put up by a competitor in the business. For many years there was little except the family and the ice-cream trade in the city, and a few thousand tons of ice was an ample supply. As the city grew in population, however, and industries sprang up, and especially after the port became a point for packing and shipping meats, the demand for ice increased. In 1860 James P. Smith & Co., now next to the largest concern in the city trade, began operations. One company

after another was started, as the opportunities for making money became known. In 1883 there are 22 regular companies in Chicago, together with a number of small concerns, with an aggregate trade not exceeded in any part of the United States except in New York city. There are $950,000 invested in ice-houses and tools. There is a storage capacity of 1,300,000 tons. From 2,600 to 3,500 men are employed a part of the winter in cutting and storing, earning from $140,000 to $180,000 in wages. A crop of from 700,000 to 1,100,000 tons is annually harvested at the various points at which the companies operate; and within the city $303,000 of capital and 835 men, earning $260,000 in wages, were employed in distributing the ice to consumers in 1880, which was a short-crop year. The actual consumption of the city is from 575,000 to 900,000 tons, varying with the dearness of the commodity.

The largest concern is the Washington Ice Company. They have store-houses located as follows:

Whence obtained.	Where stored.	Method of transportation.	Amount.
			Tons.
Calumet river	Riverdale, Illinois	Chicago and Saint Louis and Pittsburgh Railroad	24, 000
Do	Calumet, Illinois	......do	52, 000
Do	Clarke, Indiana	Pittsburgh, Fort Wayne and Chicago Railroad	27, 000
Do	South Chicago, Illinois	......do	23, 000
Do	Wildwood, Illinois	Illinois Central Railroad	13, 000
Do	Thornton, Illinois	Michigan Central Railroad	20, 000
Stone lake	La Porte, Indiana	Lake Shore and Michigan Southern Railroad	84, 000
Clear lake	......do	......do	11, 000
Fox river	Cary, Illinois	Chicago and Northwestern Railroad	24, 000
Do	Elgin, Illinois	......do	19, 000
Do	West Elgin, Illinois	Chicago, Milwaukee and Saint Paul Railroad	11, 000
Geneva lake	Wisconsin	Chicago and Northwestern Railroad	13, 000
Sturgeon bay	......do	Water transportation via lake Michigan	27, 000
	City store-houses		3, 000
Whole capacity			351, 000

The company has ice-cutting privileges without store-houses at lake Winnebago, Oshkosh, Wisconsin; Rock river, Watertown, Wisconsin; and Fox river, at Clintonville, and at Aurora, Illinois. They harvest an average of 250,000 tons. The best ice is cut at Elgin and at Laporte, and is reserved for special trades. The Wisconsin ice is, however, remarkably fine and of great thickness and density. When the Illinois streams and ponds do not freeze more than 8 or 10 inches thick, the bays of Wisconsin freeze two feet thick.

Among the other ice firms are James P. Smith & Co., who rank second only in the magnitude of their operations. They have houses in several states and at a large number of places, chiefly at Chicago, Riverside, Aurora, and Batavia, and on the Calumet lake and river, Illinois, and at Fond du Lac, Wisconsin. They do a large business in the city. Their storage capacity is equal to 90,000 tons, and they cut on the average about 60,000. A. S. Pifer & Co. cut on the Desplaines river, Illinois, on Fox river, and at Sturgeon bay, Wisconsin; storage capacity, 100,000 tons. E. A. Shedd & Co. have large houses at Wolf lake, Indiana, and in Calumet and McHenry counties, Illinois; storage room, 80,000 tons. These comprise the largest four concerns. There are three others, the O. & W. Guthrie ice company, Maginnis & Boyle, and J. H. Dale & Co., which report from 40,000 to 60,000 tons of capacity at various points in four adjoining states. The rest of the dealers handle quantities varying from 15,000 down to and below 1,000 tons. These small concerns operate mainly on the Chicago river, and in the close vicinity of the city.

With access by rail and water to so many points where pure, thick ice can be obtained, Chicago is virtually safe from an ice famine, and the industries dependent on refrigeration for running to their full capacity are seldom troubled either with short supply or excessive prices. It is of some importance to all consumers, however, whether any particular winter is, or is not, a severe one in the vicinity of the city, because the cost of transportation is a considerable element in the rates of the following year; and, if the crop must be brought from distant points, the rates rule high. Occasionally the waters of the state yield an insufficient supply. This occurred in 1877–'78 and in 1879–'80. In the winter last named from 8 to 10 inches of ice formed about Christmas time, but an untimely thaw destroyed the fields; and, as the succeeding fortnight passed without the prospect of another freeze, the companies fled northwards at once and harvested an adequate supply at Green Bay, Sturgeon Bay, Fond du Lac, and Oshkosh. In years like these high prices naturally prevail during the following summer. But there is never an ice famine now, for the companies always carry along more or less old ice from one season to another. The high rates are not due to speculation in a commodity which ranks with the necessaries of life, so much as to the greater cost of meeting the requirements of the city from distant sources of supply. With every year of good prices, moreover, the old companies put a large part of their profits into new houses and general increase of their plant, and many new companies are organized, so that the community gains the benefit of greater supply the next winter and, consequently, moderate prices. In this way the business grows steadily, and is kept commensurate with the expansion of the city and its industries. The winter of 1880–'81 was a great crop year at Chicago. One estimate of the amount cut puts it at 1,200,000 tons. It is believed that 1,000,000 tons would be nearer the truth.

At the lower estimate, however, the business nearly reached the magnitude of the product of the Hudson river in New York. There were four months of continuous cold weather. The bulk of the crop was harvested at home. Some waters were cut from three times, 12-inch ice being taken out each time. A good deal of 26-inch ice was cut that winter, all free from snow, and clear as crystal. The city derived great benefit from the large product. Prices ruled low, and ice was used with liberality by individuals who, previous to that, had been able to purchase only a limited quantity. In general, Chicago prices are lower than those in any other part of the country, except the east. In bountiful years they range from $1 50 to $2 per ton in car lots free on board; $2 to $3 per ton by the wagon load; and from $4 to $6 per ton by the 100 pounds to families. In 1878 wholesale lots sold for from $4 to $7 per ton; a few as high as $10. In 1880, which was a year of good prices, though not of scant supply, they were from $3 to $5 per ton. During the summer families and small consumers, buying by the 100 pounds, paid from $8, which was the average, to $15 per ton. In 1881 families paid $5 and $6 per ton. At retail the price in summer is always a little more than double the one which rules in the winter.

The large packing houses at the Union stock yards are the largest consumers of ice in Chicago. The brewers, however, use large quantities. The proprietors of both classes of establishments put in their own ice as far as possible. Of the about 350,000 tons which they require, 100,000 tons on an average are harvested under their own direction, at a cost of from $1 to $2 50 per ton, delivered in the house. They employ men who are little more than day laborers, having idle teams, to cut in the outskirts of the city and haul it directly to the houses. Sometimes the cost exceeds little more than the wages paid the men. In such cases it falls below $1 per ton. One large firm reports getting ice at a cost of 16 cents per ton.

MISSOURI.

Missouri is almost on the southern edge of the ice belt. No natural ice forms in the states southward of her, and the whole region to the gulf depends upon Missouri and the upper Mississippi for its supply. The only exception is the city of New Orleans, which purchases ice from Maine. The trade of the upper Mississippi naturally centers at Saint Louis. The city is, in the first place, the largest consumer of this region. She requires about 250,000 tons yearly for her own use, and various large companies have been formed among her merchants to gather and supply her with this large quantity of ice. In the next place, the city is the center of a network of railroads extending to every part of the northwest, and she also has extended water communication, by which means if the crop fails at Saint Louis ice can be drawn from a hundred other localities where it is sure to freeze from 15 to 20 inches thick. And, finally, the city is the best point for shipping ice to the southern markets; there is always a sufficient depth of water from Saint Louis southward to float the largest boats employed in the trade, even in the dryest months of the summer. The tonnage of Saint Louis is also immense. She also has railroads to Texas. All these advantages tend to make the city the ice market of the Upper Mississippi.

To supply the wants of Saint Louis and the southern trade a crop of 550,000 tons is annually required. About 270,000 tons are consumed in the city, and 280,000 are sent south to Helena, Arkansas City, Greenville, Memphis, Vicksburg, Natchez, New Orleans and other points on the lower rivers. Of late years it has not been possible to obtain a full supply in the immediate vicinity of Saint Louis in more than one year out of two. In severe winters, with steady weather, the river near the city and the ponds and stone quarries will yield an abundance of ice about a foot thick. But if a good crop is harvested in one winter it is more than likely that no ice of any amount will form the following winter, or the crop will be spoiled by a thaw and a rise in the river. There have been many years of great scarcity, and the prices of ice have fluctuated in a surprising manner. An average wholesale price, in which there is a profit, is $5 per ton, the ordinary range being from $3 25 to $6. But in 1863 ice sold in Saint Louis for $30 and $40 a ton. In 1876 it sold by the car load, early in the season, for $7 50 per ton, and during the summer rose to $15 and $16; the retail price to families was $20. In years of scarcity the greatest sufferers are the breweries and meat-packers of the city. They take half the quantity consumed by the city, and the wholesale price for the year is of immediate importance to them. The uncertainty of the local harvest has led to an extension of the operations of all the Saint Louis ice-cutters over the whole northwest. They have established houses at De Pue, Kingston, Peru, Peoria, Lasalle, Quincy, Alton, and other points in Illinois, as also at many places in Iowa and Minnesota, and their operations are now supplemented by local enterprises, both in the cities named and in Keokuk, Cedar Rapids, Des Moines, Burlington, and other towns having good routes of transportation to the city; occasionally the dealers resort to Toledo and Canada. The necessity of a sure supply has also led about 25 brewers and a number of meat-packers to act independently of the regular companies and lay in a supply of their own every year. They either harvest near the city or buy wherever the ice is good, filling their houses at a cost varying from 75 cents to $1 50 per ton for the ice, and $1 to $2 per ton for railroad freight. Ice is even brought from Minnesota frequently at a cost for freight of $3 per ton. One brewery firm has established storage houses at De Pue, Illinois, with a capacity of 20,000 tons, and employs a tow-boat and eight barges of its own to bring down the ice when required. The brewers and packers have a storage capacity of 175,000 tons, and they are

well satisfied, when the crop fails in the neighborhood of Saint Louis, to fill their houses at a cost of $3 to $3 50 per ton. They have to pay from $5 to $8 when they buy from regular dealers during the summer. It is estimated that about half of the ice required for Saint Louis and the southern markets is now harvested on the Illinois river.

The ice-houses of the upper Mississippi are as a rule smaller than those in the east. They are, however, constructed on the same principle. Within four or five years they have been supplied quite generally with endless-chain elevators and all the modern appliances for saving labor and expediting the harvest. One feature of western work is the mooring of a large number of model barges near the ice-houses before the ice forms, and the loading them with ice after the houses are full. These barges are often old steamboat hulls, from which the machinery has been removed. The others are regular freighting barges. They have cargo-houses on deck, and they carry from 400 to 900 tons of ice each; a few of large size carry from 1,200 to 1,500 tons each. About 100 are employed in the ice business of Saint Louis. It is not unusual to load from 60 to 75 of these boats with about 60,000 tons of ice in all in the course of the winter. This is especially a popular practice on the Illinois river. When the rivers open, either through some unexpected thaw or in the spring time, the barges are towed to the city and their cargoes are discharged. The shipments to the lower river are always by this class of boats.

The thickness of the ice varies with the locality and the season. Around Saint Louis the usual thickness is from 8 to 10 inches. On the rivers in Illinois ice of a thickness of from 10 to 15 inches is obtained. In Minnesota and Wisconsin a supply of hard clear ice can be obtained from 16 to 24 inches thick.

One of the growing points in the Saint Louis district is Quincy, Illinois. This city has long supplied the market with a good deal of excellent ice cut from a bay three miles long and a quarter mile wide. Her nearness to market and comparative security against the disastrous floods which destroy the ice-houses at other points from time to time are advantages which have had great influence on her trade. She has now a storage capacity of 160,000 tons, and her dealers sell to the lower market direct without the intervention of the Saint Louis companies. They ship by barge and railway-car to the most distant points. Some of her trade is by rail with Texas. The ice is sent in refrigerator cars carrying 12 tons each. It is from 5 to 7 days en route. Upon its arrival it is unloaded into 100-ton ice-houses, the walls open at the top, and it is then covered with sawdust. Two other points of great activity are Hannibal, Missouri, where about 75,000 tons are cut yearly, whence shipments are made to Texas direct, as well as to other southern states; and Cedar Rapids, Iowa, where as much as 100,000 tons is sometimes cut. The other western towns tributary to the river market cut from 10,000 to 45,000 tons each.

In Minnesota and Wisconsin a hard clear article is harvested, ranging from 16 to 24 inches.

The returns of the dealers indicate an average waste of 20 per cent. in shipping ice to southern markets. There is from 5 to 10 per cent. waste in bringing ice to the city for local consumption, and 20 per cent. in distribution.

Experiments have been made both by brewers and by regular dealers in Saint Louis during the last 10 years in the manufacture of artificial ice. On the whole, results have not been satisfactory. Natural ice is still preferred as cheaper and better.

THE GULF STATES.

The memoranda in the first part of this report on the birth of the ice business in the United States show that a large part of the trade of Frederic Tudor, of Boston, was with the southern states. In 1817, he sent a vessel to Savannah; in 1818, one to Charleston; and in 1820, a first shipment was made to New Orleans. From that beginning, a trade of from 75,000 to 100,000 tons of ice yearly has grown up from Boston, the Kennebec river, and other localities in Maine, and from New York and Philadelphia. The principal destinations of cargoes from the north have been Savannah and New Orleans. Both cities are large consumers, and in addition thereto, Savannah has been the gateway through which ice has been sent by water to Augusta, and by rail to Macon, Atlanta, and other interior towns. Other ports to which northern shipments have been made are Wilmington, North Carolina, Charleston, South Carolina, Jacksonville, Appalachicola, and Pensacola, Florida, Mobile, Alabama, and Galveston, Texas. A waste of from 25 to 30 per cent. has attended these shipments. The cost of freight has been from $1 50 to $2 50 per ton. After the landing of the cargo, a further waste of not less than 25 per cent., and often as much as 40 per cent., has been met with in distribution. The wholesale price of northern ice has, as a consequence, been not less than $10 per ton in the coast cities, and has often risen to $30 per ton. The regular charge to consumers has been $20 per ton; but in epidemic years on the coast, and in inland towns, often as much as $60 and $75. The high prices made ice, for fifty years, a luxury to be indulged in only by the prosperous. The masses in the cities were unable to afford the costly pleasure of its consumption. Ice does not form naturally in the south; and the entire lack of a local supply has at times been felt severely, especially in the years of the prevalence of yellow fever, when quarantine regulations cut her cities off from communication with the rest of the country.

For fifteen years efforts have been made to reduce the cost of ice in the south and render her, in a measure, independent of outside sources of supply. Tennessee and Georgia have imported extensively from the Ohio River region by rail. The lower Mississippi has bought in the Saint Louis region; and Texas has imported by rail. Enterprise has, however, been chiefly in the direction of the manufacture of artificial ice. The inventors of ice-

machines have found the south their most profitable field of operations. In order to introduce their patents they have followed the practice of selecting some inland town of considerable population, in which their product would not come into too direct competition with northern ice. They have set up their machines, retaining a part interest in them, and begun the process of manufacture, supplying, so far as possible, the local demand, and, in many cases, selling their surplus to other communities easily accessible by rail or by water. In other places the business has been undertaken by local capital. There is scarcely a large town in the south in which the experiment of manufacture has not been tried with more or less success. In Atlanta six machines, producing about 50 tons of ice a day in the aggregate, have now been in operation for several years. In Augusta there have been three, producing about 20 tons a day. Austin has had two companies, which have been making, jointly, 10 tons a day, in blocks of from 25 to 60 pounds each, the larger blocks being for the trade with surrounding towns and villages. Ice-machines are especially numerous in Texas. New Orleans now has three factories for making artificial ice. The cost of production has been reduced to about $5 per ton in most places, which is a trifle below the rate at which ice can be delivered in Tennessee and Georgia by rail from the Ohio river, and considerably below the cost of the article from Maine, delivered in inland southern towns. With this advantage in its favor, the business of manufacture is steadily growing at all points at a distance from the sea-coast. The prospect is fair that they will soon be independent of outside sources of supply, although it will be many years before the cost to small consumers will fall anywhere nearly as low as in the north. On the sea-coast northern ice still has the preference. It can be landed more cheaply than the local article can be made; and by purchasing in Maine or Massachusetts the dealers avoid the heavy risks of experimenting with expensive plant and imperfect methods of manufacture. The solitary exception is the city of New Orleans, which, though still buying northern ice, is nevertheless manufacturing on an extensive scale.

The principal drawbacks to the making of artificial ice in the south have been the imperfection of the machines, resulting in a contamination of their product by the escape of the ammonia, ether, or other refrigerating fluid; the difficulty of securing in a hot climate the efficiency manifested by the machines in a cooler region; and the heavy expense of operation. The failures have been as numerous as the successes. The genius and energy of the inventors have triumphed, however, at last. Leakages have been stopped, expenses have been reduced, and practical results have been obtained. The machines most preferred at present are the ones using ammonia as the means of refrigeration.

In New Orleans, according to the report of Chief Special Agent E. A. Deslonde, the quantity of ice actually consumed in 1880 was about 32,000 tons, requiring a supply amounting to 55,000 tons. The consumption has at times been as high as 50,000 tons, requiring a supply of 91,000 tons. These figures were arrived at both by a study of the returns of the ice companies and by a careful inquiry among 210 consumers (families, hotels, saloons, fishermen, etc.). The business has grown since 1880, and may be considered at the present time as large as the highest figures above given. The artificial product is made by two corporations, the Louisiana Ice Manufacturing company and the New Orleans Ice Manufacturing company, both having large capital, with extensive establishments, machinery, and appliances. The full capacity of production of these concerns has not yet been fully demonstrated. The Louisiana company was formed in 1868 and was the pioneer in the business. At the outset of its career, after lavish expenditure on costly, but imperfect machinery and appliances, its managers found the result of their operations far from satisfactory. Their losses were disastrous. It has only been within the past few years, and after the adoption of new methods and many mechanical improvements, that they have succeeded in making blocks of 100 pounds, in quality and appearance equal to the best river ice secured in the north. Their earlier product was in 20-pound blocks, and was often damaged by an ammoniacal taste and many impurities. Their final success dissipated the prejudice against the use of artificial ice and enabled them to enlarge their plant by the construction of a second factory. The company now has 10 Carré machines, 6 in one factory and 4 in the other, with a total capacity of 45,000 tons a year. The New Orleans company was started in 1880. It employs the California invention of J. M. Beath, which was first put into operation in Los Angeles and San Francisco and afterwards in Atlanta, Chattanooga, and Nashville. The machine uses liquid anhydrous ammonia as the refrigerating fluid, and differs from the Carré machine by making ice not in blocks in pans, but by freezing it into solid walls on the surface of a network of iron pipes, the water descending upon the pipes in a shower. The product of the factory in 1880 did not exceed 1,800 tons, but with the completion of its plant a capacity of 30 tons per day has been attained. The operations of these two companies have materially reduced the price of ice to consumers in the city. The wholesale price has often ranged as high as $30 a ton; it has been lowered to $10 by the competition between the manufacturers and the importers. To small consumers the price has always been extravagantly high. The distribution has been made by small drivers and dealers who have not practiced weighing the ice, but who have been accustomed to saw or split off pieces by guessing, and call them of such and such a weight. From information obtained through many sources, it appears that it has not been unusual to charge customers 2 cents a pound, or $40 a ton, and in epidemic years or periods of ice famine, from 3 to 5 cents a pound, or from $60 to $100 per ton. Local production has reduced these retail rates to an average of 1 cent per pound, or $20 per ton. Lowering of cost to the consumer has had the effect, as might be expected, of increasing the consumption of ice since 1880. Families, hotels, and saloons are buying in large quantity; and the traffic in fish,

oysters, fresh meats, and vegetables during the summer months has been greatly promoted. It is confidently anticipated by both the manufacturers and the importers that the business will hereafter expand rapidly, year by year. With prices as low as in the north the consumption of New Orleans would probably exceed 250,000 tons yearly.

Distribution in New Orleans is not yet systematically done. Sales are generally for cash. Few accounts are kept. The ice is sold to wagon-peddlers and hucksters, of whom there are about 100 owning carts and horses of an average value of $158 each, and these peddlers sell from the wagon with a crude method, which usually, but not always, leaves them a little more money at the end of the day than they had at the beginning.

ON THE PACIFIC COAST.

The coolness of the summers along the Pacific coast obviate the necessity for much ice cutting. The preservation of fish and meats calls for only a small amount of ice. The hotels and barrooms, and the more luxurious families are the principal consumers. San Francisco is the principal market, but the consumption does not exceed from 20,000 to 40,000 tons a year at present. The first ice was brought from Sitka, in Alaska, by trading vessels. A company was formed to deal in the commodity while that region was still under Russian control. The government made a concession to the company, and small amounts of ice were brought to the market and sold there at retail for 5 and 6 cents a pound, that is to say, from $100 to $120 per ton. The Pacific railroad opened up new and nearer sources of supply in the Sierra Nevada mountains, and the price was cut down to about $40 per ton at retail. Good ice, from 10 to 24 inches in thickness, is obtained in the mountains in abundance. At Nevada City it forms 4 feet thick. The high freights retarded the business, however, they being about $100 per car load of 10 or 12 tons. A reduction of this rate to $70 per car resulted in the abandonment of the Alaska trade. The high prices led to the introduction of ice machines in all the principal cities of California, especially in San Francisco, Sacramento, and Los Angeles, and for a number of years a lively war was carried on between the mountain companies and the machine companies. A compromise was finally effected, by which the former were to load ice on the cars in the mountains at $3 per ton, $7 per ton being added for freight, and the machine firms were to sell at the wholesale price of $10 per ton. A new competition sprang up, however, with new and rival companies of both classes, and the retail prices of ice have been cut down, within two or three years, to $10 and $15 per ton. Machines are being constantly introduced in every part of the state subject to warm summers. Low prices seem hereafter assured. Farther up the coast, in Oregon and in Washington, the need of ice is seldom felt. There is plenty of the commodity on the higher lands, and when needed it can be harvested in abundance.

Statistics of consumption of ice in twenty principal cities of the United States, from October 1, 1879, to September 30, 1880.

Distribution, etc.	Amount.	Remarks.
BOSTON, MASSACHUSETTS.	*Tons.*	
Harvested	660,000	There are 14 companies, with a capital of $406,000, employing 308 men. Wages paid during the year, $205,090. Value of ice sold and consumed, $1,025,000. Of the amount shipped to other places 169,000 tons is not included in distribution by months, having been shipped at irregular intervals. Wholesale prices during 1880, from $2 to $6 per ton; retail, by the 100 pounds, 15 and 25 cents in the winter and spring; 40 and 50 cents in the summer.
Sold to customers	381,588	
To brewers	13,317	
To butchers and meat-packers	45,702	
To butter dealers	4,375	
To ships and shipped to other places	173,575	
To private families	127,471	
To miscellaneous consumers	17,148	
Consumed during—		
October	19,653	
November	9,522	
December	5,212	
January	4,026	
February	4,036	
March	6,604	
April	8,355	
May	23,075	
June	24,685	
July	40,508	
August	37,422	
September	29,470	

Distribution, etc.	Amount.	Remarks.
PROVIDENCE, RHODE ISLAND.		
Harvested	40,970	There are 9 companies, with a capital of $34,500, employing 100 men. Wages paid during the year, $41,700. Value of ice sold and consumed, $320,000. In 1880, wholesale prices ranged from $5 50 to $10 per ton; retail prices, 25 cents to the end of February, 50 cents in March and April, 60 cents in the summer.
Sold to customers	32,800	
To brewers	300	
To butchers and meat-packers	8,100	
To butter dealers	5,850	
To ships and shipped to other places	150	
To private families	16,200	
To miscellaneous consumers	2,200	
Consumed during—		
October	2,982	
November	2,236	
December	1,489	
January	1,490	
February	1,491	
March	1,490	
April	1,492	
May	2,240	
June	2,982	
July	5,962	
August	5,964	
September	2,982	

Distribution, etc.	Amount.	Remarks.
BROOKLYN, NEW YORK.		
Harvested	528,000	There are 4 companies, with a capital of $190,000, employing 661 men. Wages paid during the year, $329,210. Value of ice sold and consumed, $1,900,000. Wholesale prices to wagons at the ice depots and to large consumers, from $3 to $6; average retail price in summer, 55 cents for 100 pounds.
Sold to customers	334,536	
To brewers	67,540	
To butchers and meat-packers	17,040	
To butter dealers	....	
To ships and shipped to other places	7,230	
To private families	168,760	
To miscellaneous consumers	73,966	
Consumed during—		
October	24,021	
November	10,961	
December	8,493	
January	10,638	
February	12,531	
March	17,358	
April	26,953	
May	34,691	
June	43,991	
July	61,630	
August	44,193	
September	39,076	

Distribution, etc.	Amount.	Remarks.
NEW YORK, NEW YORK.	*Tons.*	
Harvested	1,885,000	There are 11 companies, with a capital of $638,000, employing 2,502 men. Wages paid during the year, $1,183,480. Value of ice sold and consumed, $6,190,000. Sales for shipment were mainly for refrigeration of meats, etc., on steam-vessels. Wholesale prices in 1880, from $3 to $7, and up to $10 per ton; in small lots, during June and July, prices ran up to $20 in some cases; retail prices, 20 to 30 cents per 100 pounds until the end of February, then up to 50, 60, and 75 cents in June, July, and August; one company charged as high as $1 per 100 pounds.
Sold to customers	956,559	
To brewers	185,247	
To butchers and meat-packers	116,030	
To butter dealers	31,275	
To ships and shipped to other places	38,356	
To private families	425,887	
To miscellaneous consumers	199,764	
Consumed during—		
October	78,159	
November	36,306	
December	28,463	
January	31,077	
February	38,629	
March	54,043	
April	76,532	
May	92,313	
June	122,596	
July	167,590	
August	124,530	
September	106,321	

Distribution, etc.	Amount.	Remarks.
JERSEY CITY, NEW JERSEY.		
Harvested	51,580	There are 4 companies, with a capital of $49,000, employing 100 men. Wages paid during the year, $31,500. Value of ice sold and consumed, $270,000. To dealers and large consumers, wholesale prices from $6 to $8 in the summer; butchers, hotels, and families were supplied at from 50 to 75 cents per 100 pounds.
Sold to customers	33,552	
To brewers	2,909	
To butchers and meat-packers	3,811	
To butter dealers	300	
To ships and shipped to other places	4,472	
To private families	14,094	
To miscellaneous consumers	7,975	
Consumed during—		
October	4,079	
November	1,391	
December	1,505	
January	762	
February	402	
March	770	
April	1,572	
May	3,660	
June	4,849	
July	5,315	
August	4,386	
September	4,841	

Distribution, etc.	Amount.	Remarks.
NEWARK, NEW JERSEY.		
Harvested	89,390	There are 5 companies, with a capital of $74,040, employing 85 men. Wages paid during the year, $43,975. Value of ice sold and consumed, $360,000. Wholesale prices in 1880, from $3 50 to $8; retail price to families from 50 to 70 cents per 100 pounds.
Sold to customers	52,040	
To brewers	18,200	
To butchers and meat-packers	4,737	
To butter dealers	....	
To ships and shipped to other places	....	
To private families	16,603	
To miscellaneous consumers	12,500	
Consumed during—		
October	2,700	
November	1,072	
December	1,424	
January	1,757	
February	3,001	
March	3,597	
April	2,247	
May	4,448	
June	6,329	
July	8,136	
August	9,167	
September	8,162	

Statistics of consumption of ice in twenty principal cities of the United States, etc.—Continued.

Distribution, etc.	Amount.	Remarks.
TROY, NEW YORK.	*Tons.*	
Harvested	52,000	There are 13 companies, with a capital of $32,900, employing 59 men. Wages paid during the year, $20,585. Value of ice sold and consumed, $285,000. About 25,000 tons sold from the houses direct, for shipment and other purposes, at about $3 50 per ton. Retail prices to families, 10 cents per 100 pounds in winter, and 40 to 50 cents in the summer.
Sold to customers	43,560	
To brewers	2,585	
To butchers and meat-packers	2,600	
To butter dealers	45	
To ships and shipped to other places	19,900	
To private families	18,350	
To miscellaneous consumers	80	
Consumed during—		
October	1,640	
November	1,453	
December	1,091	
January	850	
February	850	
March	898	
April	1,360	
May	2,045	
June	7,025	
July	8,875	
August	9,920	
September	7,543	
ALBANY, NEW YORK.		
Harvested	121,500	There are 14 companies, with a capital of $48,200, employing 117 men. Wages paid during the year, $29,420. Value of ice sold and consumed, $190,000. About 22,000 tons sold for shipment to New York for $3 to $6 per ton; wholesale rate to the public, the same; retail prices to families, etc., 10 cents to April, and then 40 and 50 cents per 100 pounds.
Sold to customers	90,550	
To brewers	12,500	
To butchers and meat-packers	11,250	
To butter dealers	20	
To ships and shipped to other places	22,000	
To private families	44,680	
To miscellaneous consumers	....	
Consumed during—		
October	4,120	
November	2,530	
December	1,470	
January	6,260	
February	2,235	
March	2,060	
April	4,475	
May	5,045	
June	12,950	
July	15,700	
August	18,000	
September	12,005	
BUFFALO, NEW YORK.		
Harvested	100,000	There are 45 companies, with a capital of $135,000, employing 268 men. Wages paid during the year, $76,250. Value of ice sold and consumed, $325,000. 22 brewers and 14 butchers and meat-packers in Buffalo cut their own ice to the amount of 57,250 tons, at a cost of about $1 per ton, and this quantity is incorporated in the above statistics at the valuation of $1 per ton. Wholesale prices, $2 to $6 per ton; retail prices, 40, 50, and 60 cents per 100 pounds in the summer months.
Sold to customers	95,750	
To brewers	47,605	
To butchers and meat-packers	22,645	
To butter dealers	....	
To ships and shipped to other places	800	
To private families	23,200	
To miscellaneous consumers	1,500	
Consumed during—		
October	8,377	
November	5,509	
December	2,980	
January	2,527	
February	2,528	
March	3,493	
April	6,007	
May	8,420	
June	12,462	
July	16,334	
August	14,843	
September	12,270	

Distribution, etc.	Amount.	Remarks.
CLEVELAND, OHIO.	*Tons.*	
Harvested	146,480	There are 28 companies, with a capital of $167,100, employing 1,044 men. Wages paid during the year, $70,818. Value of ice sold and consumed, $320,000. 16 firms of brewers and packers cut and themselves consumed 100,710 tons of ice, valued at $55,000, which are incorporated above. Wholesale prices, from $2 to $6 per ton; retail prices in the summer, from 50 to 60 cents per 100 pounds.
Sold to customers	129,785	
To brewers	21,842	
To butchers and meat-packers	87,350	
To butter dealers	150	
To ships and shipped to other places	940	
To private families	18,715	
To miscellaneous consumers	788	
Consumed during—		
October	5,226	
November	3,763	
December	2,221	
January	2,220	
February	2,099	
March	3,952	
April	7,544	
May	15,322	
June	17,698	
July	24,033	
August	23,989	
September	21,718	
CINCINNATI, OHIO.		
Harvested	283,000	There are 41 companies, with a capital of $248,000, employing 967 men. Wages paid during the year, $65,241. Value of ice sold and consumed, $1,200,000. 38 firms of brewers and packers cut 45,942 tons of ice for their own consumption, valued at $68,000, which are incorporated above. Wholesale prices varied from $2 in the winter to $6 and $10 in the summer; retail prices in the winter, 25 to 35 cents per 100 pounds; 50 to 60 cents in the summer.
Sold to customers	206,885	
To brewers	47,100	
To butchers and meat-packers	40,040	
To butter dealers	1,025	
To ships and shipped to other places	6,800	
To private families	77,420	
To miscellaneous consumers	34,500	
Consumed during—		
October	11,664	
November	9,287	
December	6,132	
January	6,732	
February	7,832	
March	11,087	
April	16,406	
May	20,923	
June	25,434	
July	28,928	
August	33,099	
September	29,361	
CHICAGO, ILLINOIS.		
Harvested	710,000	There are 53 companies, with a capital of $303,500, employing 835 men. Wages paid during the year, $259,815. Value of ice sold and consumed, $2,400,000. 31 firms of brewers, packers, and brick-makers and others having an independent business of their own cut 103,643 tons of ice either for their own consumption or for the general trade, valued at $156,000. Wholesale prices varied exceedingly, each firm having its own; they ran from $1 25 to $5 per ton, a few sales going higher. Retail prices, 20 cents per 100 pounds in the winter, and from 35 to 50 cents in the summer. One company reported retail sales at 75 cents per 100 pounds.
Sold to customers	576,687	
To brewers	73,238	
To butchers and meat-packers	273,779	
To butter dealers	4,110	
To ships and shipped to other places	17,521	
To private families	188,219	
To miscellaneous consumers	19,820	
Consumed during—		
October	53,100	
November	23,045	
December	29,534	
January	31,468	
February	18,062	
March	18,128	
April	32,014	
May	51,623	
June	67,551	
July	93,076	
August	88,635	
September	70,451	

Statistics of consumption of ice in twenty principal cities of the United States, etc.—Continued.

Distribution, etc.	Amount.	Remarks.
DETROIT, MICHIGAN.	*Tons.*	
Harvested	165, 850	There are 21 companies, with a capital of $50,050, employing 228 men. Wages paid during the year, $32,075. Value of ice sold and consumed, $995,000. 15 firms of brewers and packers consumed 32,050 tons of ice, which was cut for them by contract at an average price of $1 50 per ton stored in the house. Prices to large consumers, $8 and $10 per ton the season through; to families, about 60 cents per 100 pounds.
Sold to customers	138, 450	
To brewers	23, 550	
To butchers and meat-packers	13, 500	
To butter dealers	....	
To ships and shipped to other places	5, 000	
To private families	96, 400	
To miscellaneous consumers	....	
Consumed during—		
October	3, 635	
November	2, 160	
December	1, 135	
January	310	
February	575	
March	880	
April	1, 880	
May	4, 470	
June	20, 050	
July	44, 540	
August	42, 500	
September	16, 315	
INDIANAPOLIS, INDIANA.		
Harvested	79, 500	There are 11 companies, with a capital of $13,100, employing 148 men. Wages paid during the year, $22,364. Value of ice sold and consumed, $625,000. Retail prices, 50, 60, and 70 cents per 100 pounds.
Sold to customers	61, 246	
To brewers	12, 740	
To butchers and meat-packers	36, 650	
To butter dealers	600	
To ships and shipped to other places	1, 156	
To private families	8, 900	
To miscellaneous consumers	1, 200	
Consumed during—		
October	4, 208	
November	1, 829	
December	814	
January	779	
February	1, 433	
March	1, 152	
April	3, 124	
May	5, 348	
June	9, 159	
July	12, 480	
August	13, 055	
September	7, 865	
LOUISVILLE, KENTUCKY.		
Harvested	43, 000	There are 15 companies, with a capital of $33, 000, employing 103 men. Wages paid during the year, $28,857. Value of ice sold and consumed, $330,000. Ice at Louisville is about wholly imported from the north and sells high. Brewers pay $5 and $6 at wholesale. Retail prices in 1880, 30 to 75 cents per 100 pounds in the winter, and from 75 cents to $1 50 in the summer months. Six of the above concerns are brewers and packers who contract for their supply.
Sold to customers	35, 100	
To brewers	20, 844	
To butchers and meat-packers	2, 506	
To butter dealers	220	
To ships and shipped to other places	470	
To private families	10, 040	
To miscellaneous consumers	1, 020	
Consumed during—		
October	3, 164	
November	1, 147	
December	752	
January	1, 461	
February	1, 142	
March	1, 944	
April	2, 857	
May	3, 475	
June	4, 687	
July	5, 697	
August	4, 850	
September	3, 924	

Distribution, etc.	Amount.	Remarks.
SAINT LOUIS, MISSOURI.	*Tons.*	
Harvested	270, 000	There are 33 companies, with a capital of $650,400, employing 535 men. Wages paid during the year, $153,607. Value of ice sold and consumed, $1,400,000. Brewers purchased largely of regular dealers, at $5 and $6 per ton. Wholesale prices were $3 50 and $4 in the winter, rising to $8 and $9 in June, and declining to $7 and $8 for the rest of the summer; retail prices, 40 cents per 100 pounds in the winter, and from 60 to 75 cents in summer.
Sold to customers	205, 641	
To brewers	92, 774	
To butchers and meat-packers	6, 216	
To butter dealers	500	
To ships and shipped to other places	6, 577	
To private families	99, 074	
To miscellaneous consumers	500	
Consumed during—		
October	5, 026	
November	3, 066	
December	2, 019	
January	9, 054	
February	21, 133	
March	26, 379	
April	23, 605	
May	17, 800	
June	23, 272	
July	28, 841	
August	27, 070	
September	18, 376	
PHILADELPHIA, PENNSYLVANIA.		
Harvested	700, 000	There are 81 companies, with a capital of $536,220, employing 1,278 men. Wages paid during the year, $364,148. Value of ice sold and consumed, $1,950,000. Seventy firms of brewers, packers, and provision dealers cut their own ice, amounting to 56,270 tons, worth $62,000. Wholesale prices rose from $2 25 per ton in the winter to $5 and $6 in the summer; retail prices, 20 cents per 100 pounds in the early part of the year, 40 cents in summer.
Sold to customers	376, 990	
To brewers	92, 371	
To butchers and meat-packers	39, 537	
To butter dealers	6, 313	
To ships and shipped to other places	40, 783	
To private families	195, 655	
To miscellaneous consumers	21, 311	
Consumed during—		
October	28, 627	
November	13, 746	
December	9, 013	
January	8, 536	
February	13, 747	
March	19, 512	
April	13, 960	
May	31, 675	
June	43, 267	
July	76, 668	
August	65, 460	
September	52, 770	
BALTIMORE, MARYLAND.		
Harvested	165, 000	There are 7 companies, with a capital of $104,000, employing 354 men. Wages paid during the year, $102,900. Value of ice sold and consumed, $1,200,000. Retail prices, 20 cents per 100 pounds until April, then a gradual rise to 50 cents in the hot months; 75 cents in some cases in August and September. Wholesale price, about $8.
Sold to customers	124, 096	
To brewers	29, 103	
To butchers and meat-packers	17, 579	
To butter dealers	647	
To ships and shipped to other places	4, 863	
To private families	61, 274	
To miscellaneous consumers	10, 630	
Consumed during-		
October	12, 989	
November	4, 533	
December	3, 388	
January	3, 302	
February	3, 845	
March	8, 839	
April	9, 473	
May	11, 511	
June	15, 376	
July	21, 036	
August	17, 225	
September	12, 581	

Statistics of consumption of ice in twenty principal cities of the United States, etc.—Continued.

Distribution, etc.	Amount.	Remarks.	Distribution, etc.	Amount.	Remarks.
WASHINGTON, DISTRICT OF COLUMBIA.	*Tons.*		NEW ORLEANS, LOUISIANA.	*Tons.*	
Harvested	75,000	There are 3 companies, with a capital of $42,300, employing 134 men. Wages paid during the year, $65,780. Value of ice sold and consumed, $600,000. Prices, in winter, 75 cents to $1 per 100 pounds; from April to October, $1 to $1 50 per 100 pounds.	Harvested	55,000	There are 4 companies, with a capital of $567,000, employing 172 men. Wages paid during the year, $52,600. Value of ice sold and consumed, $315,000.
Sold to customers	53,410		Sold to customers	31,530	
To brewers	13,600		To brewers	....	
To butchers and meat-packers	7,700		To butchers and meat-packers	8,526	
To butter dealers	....		To butter dealers	....	
To ships and shipped to other places	....		To ships and shipped to other places	1,118	
To private families	32,185		To private families	21,886	
To miscellaneous consumers	....		To miscellaneous consumers	....	
Consumed during—			Consumed during—		
October	3,400		October	2,000	
November	2,435		November	2,000	
December	1,732		December	2,000	
January	1,200		January	2,000	
February	1,600		February	2,000	
March	2,550		March	2,000	
April	3,465		April	2,030	
May	5,308		May	2,300	
June	6,950		June	3,200	
July	8,310		July	4,500	
August	9,400		August	4,300	
September	7,060		September	3,200	

INDEX.